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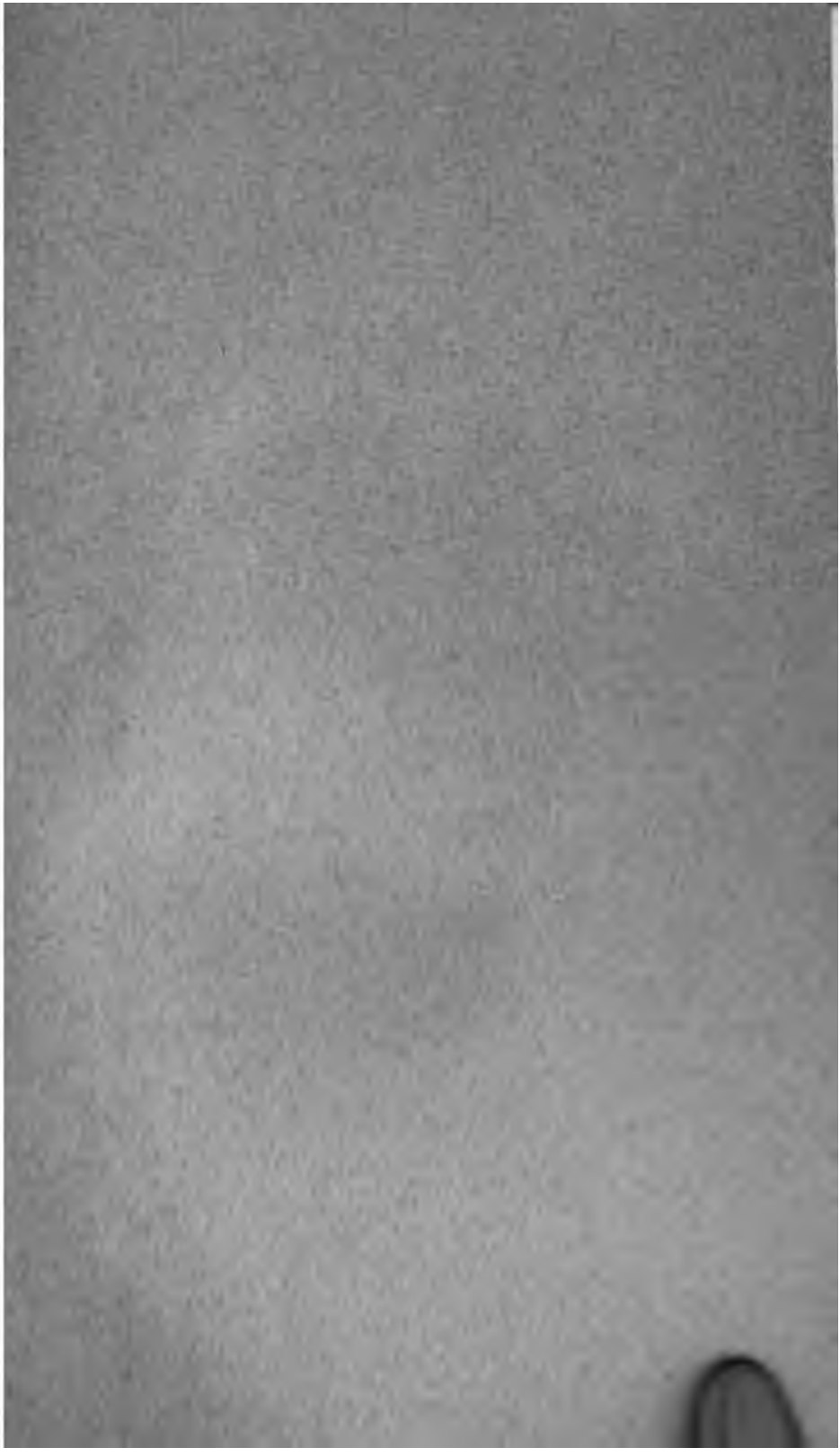

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V.—(In three sections).—To illustrate Mr. BROCKBANK and Mr. DE RANCE's paper on "The Levenshulme Limestones." 282

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during the previous session, and published in the last volume of its *Memoirs and Proceedings.* Diagrams of the apparatus were exhibited and explained. Referring to the authors' conclusion that chlorine and hydrogen are capable of direct combination at a high temperature, Dr. BOTTOMLEY pointed out that the experiments seemed to negative an hypothesis which had lately been promulgated to the effect that no two bodies combine except in the presence of a third body—an electrolyte.

Mr. P. CAMERON read a paper entitled "Description of a new genus of European *Tenthredinidæ* and of some undescribed *Chalcididæ*."

A conversation on the possibility of holding injurious insects in check by the introduction of such parasites ensued.

The Rate of Explosion of Hydrogen and Chlorine in the dry and in the moist states. By Harold B. Dixon, M.A., F.R.S., Professor of Chemistry; and Mr. J. A. Harker, Dalton Chemical Scholar in the Owens College.

(*Received October 21st, 1890.*)

This research, a continuation of our previous work on the combination of chlorine and hydrogen, was made with the object of ascertaining whether, in the explosive combination of these gases, the action was a direct one, or whether the union was brought about by the interaction of water-vapour present. We have already shown (confirming Pringsheim's statement) that the gases, when thoroughly dried, were not nearly so sensitive to light as when in the moist condition; about 25 times more light being necessary to explode the dry gas, than that saturated with moisture. The question remained: When once the explosion is started in a portion of the mixed gases (either by light or by a spark), is the propagation of the explosion through the unburnt gases dependent on the presence of water-vapour? The method employed to solve this problem was the same as that previously used to determine whether the combustion of carbonic oxide and of cyanogen by oxygen was effected by the interaction of water-vapour. In the case of carbonic oxide and oxygen the rate of propagation of the combustion is increased by adding water-vapour until it amounts to about 5 per cent of the mixture; in the case of

cyanogen and oxygen the rate of propagation of the combustion is diminished by the addition of vapour-water to the dry gases. The burning of cyanogen, at all events as far as the initial combustion to carbonic oxide is concerned, seems to be independent of the presence of water; whereas the combustion of carbonic oxide to carbonic acid seems to depend upon the presence of water-vapour. A measurement of the rate of explosion of hydrogen and chlorine, firstly in the dry state, and, secondly, when saturated with water-vapour seemed, therefore, likely to answer the question.

A knowledge of the velocity of the explosion-wave in hydrogen and chlorine is also of great theoretical interest in view of Berthelot's conclusions regarding the nature of explosions: for hydrogen and chlorine combine without condensation, and the gas formed approximates to a perfect gas.

The gas used in the experiments was made by the method so minutely studied by Bunsen and Roscoe, namely, the electrolysis of hydrochloric acid. The acid used (of specific gravity about 1·20) was partly saturated with chlorine gas, to save the long preliminary electrolytic saturation otherwise necessary. The electrolytic cell was of glass and contained about 3 litres of acid. It was provided with two carbon electrodes, about 10 mm. thick, cemented by paraffin into glass tubes, which dipped below the level of the liquid. The upper ends of these tubes were filled with mercury, making contacts for the battery wires. The delivery tube contained a series of bulbs holding about 5 cc. of water. This retained the greater part of the hydrochloric acid carried over by the chlorine and hydrogen. From this the gas was conducted through a Winckler worm, a series of bulbs, and finally a large U-tube, all filled with *boiled* sulphuric acid. Attached to the U-tube was a threeway tap, one limb of which led to the explosion tube, and the

other to a tower filled with lime and charcoal. The whole apparatus was mounted on a stand, and the glass tubes were fused together after filling. The current used was supplied from seven large secondary cells, giving a voltage of about 15. It passed through two adjustable resistances; one, iron wire; the other, carbon; then through a small low-resistance Kohlrausch ammeter; then to the electrolyser. About 4 ampères was the greatest current we could use without heating the liquid too much.

We first experimented with a view to discover a material suitable for the explosion tube. Pieces of pure lead sealed up in dry chlorine are not much acted on, the colour of the gas being visible after some weeks. We, therefore, thought that a lead tube, after a certain time would become coated internally with chloride and so be available at least for the experiments with dry gases. After many hours of saturation with dry chlorine, we found that the gas continued to be absorbed with formation of a white volatile solid decomposed by water, which analysis shewed to be chloride of tin. This issued as a white cloud from the end of the explosion tube. The best electrolytic mixture we could obtain from the end of the explosion tube contained not more than 80 % combustible gas (H_2+Cl_2).

We, therefore, proceeded to have drawn some strong glass tubing in long lengths. We succeeded in getting two lengths of 30 and 34 feet respectively. These were slung from a long ladder fixed against the wall of a dark corridor. One end of each tube was then bent and fastened to the other, so that the whole tube was about 21 yards long. Various joints were used, plaster of Paris, certain cements, and also fused chloride of silver, but none of these held so well as a piece of strong rubber, slipped over the ends which were previously ground smooth and pressed close together. The rubber, being coated on the inside with paraffin, was acted on very slowly by the chlorine. Fastened

to the two free ends of the tubes were steel flanges with ground faces. Their interior was lined with glass.

The gas passed directly from the electrolytic cell through the drying tubes into the long explosion tube—driving out the air before it: at the further end it passed through an "analyser," which served to determine the composition of the gas issuing from the tube. This consisted of a large bulb holding 80 c.c., provided at the bottom with a three-branch tap leading to a funnel containing dilute KI solution and to a small bottle containing water. At the upper end was a tail-tap leading to a pipette and to a lime and coke tower. The pipette, which was constructed of narrow tubing, about 6 mm. diameter, was provided with a millimetre scale and calibrated by mercury. The tube between the three-way tap and the pipette was very fine, less than 1 mm. bore. The dry gas was passed from the explosion tube through water into the bulb, which had been previously dried; then the excess passed into the tower. After collecting the sample, the taps were all closed, the gas-pipette being completely full of water.

The bulb was first exposed for some time to diffused daylight and then to sunlight or to some magnesium flashes. The tap below was then opened to the KI reservoir, and the liquid allowed to rush up. A small residue generally remained, which was measured in the pipette. This small residue was found to be hydrogen; it was never more than 1 per cent of the whole, and in most of the experiments varied between ·2 and ·4 per cent.

To ensure complete combination between the hydrogen and chlorine in the bulb by the action of light, it was necessary to moisten the gases. The gases as used in the dry experiments may be exposed for days to sunlight without complete combination taking place. The potassium iodide serves to show that there is no chlorine left.

The filling of the explosion tube took generally two to

three hours with the average current. The whole of the generating and drying apparatus was protected from light by being covered with black cloth, and the corridor was only illuminated by one or two small gas flames, which did not have the least perceptible action on the mixture.

The method used to measure the rate of the explosion-wave was similar to that used for other gaseous mixtures, viz.: to make the explosion break two silver or platinum strips or "bridges" stretched across the tube, one near each end. These bridges carried currents, which actuated two electro-magnetic styles making traces on a moving plate. The bridges were fitted to two separate tubes, which could be rapidly joined up to the long glass explosion tube by means of steel flanges. These separate "end tubes" were charged with a mixture of oxygen and hydrogen. When the long tube was completely filled with the electrolytic hydrogen and chlorine, the two "end tubes" carrying the bridges were fastened to it, the electric connections were made to the chronograph, and the gases fired by sending a spark through the oxygen and hydrogen in the firing tube. The flame travelled down this tube, which was about 4 feet long, breaking the silver bridge at the end of it, and communicating the explosion to the hydrogen and chlorine. On reaching the end of the glass tube, the explosion broke the silver bridge fitted to the second end tube. In the few seconds which elapsed between joining on the end tubes and firing the mixture, but little diffusion of the gases was possible; and the silver bridges, being coated with paraffin, were hardly acted on by the chlorine. Between each experiment all the connections of the chronograph were reversed; so that whatever error was due to the defects of the chronograph and connections was reversed in the second experiment. The results are therefore grouped together in pairs; the means of the several pairs being closely concordant. The following are the results obtained in the first series of experiments:—

$H_2 + Cl_2$

Rate of Explosion in Metres per Second.

Dry.		Wet.	
1776	1798	1728	1757
1821		1786	
1791	1795	1740	1774
1799		1809	
1764	1787	1787	1780
1811		1772	
1728	1798		
1869			
1767	1800		
1832			
Mean..1795		Mean..1770	

Difference due to water present = 25 met. per sec.

It appears, therefore, that the explosion, once started, travels slightly faster in the dry gases than in the wet; the moisture appearing merely to act as a diluent. We propose to repeat the experiments, using a longer explosion tube.

[*Microscopical and Natural History Section.*]

Ordinary Meeting, October 13th, 1890.

ALEX. HODGKINSON, M.B., B.Sc., President of the Section, in the Chair.

There were exhibited:—By Mr. T. ROGERS, a new moss, *Homala densa*, from Oahu; by Mr. CAMERON, a number of insects, some new to science, which he proposed to describe later, also a specimen of *Isostoma Boscii*, which he had taken in his garden at Sale.

Mr. THEODORE SINGTON showed a diagram drawn to a horizontal and vertical scale of eight feet to the inch, prepared from careful measurements of each bed, of the interesting section of the Carboniferous rocks exposed in the new railway cutting adjoining Burnage Lane, Levenshulme. Mr. Sington stated that the section extended from a point 100 feet from the western face of the brickwork of Burnage Lane Bridge, where the Carboniferous rocks disappear under the overlying Permian red sandstones, to about 312 feet from the eastern face of the brickwork of the bridge. When first exposed the section consisted of richly coloured blue, greenish, purple, red, and yellow clays, which subsequently lost their brilliant colours, interbedded with numerous layers of limestone, corresponding with those occurring at Ardwick. The limestone beds vary in thickness from 4 inches to 4 feet 6 inches; the principal bed occurs at the eastern end of the section. It is the one now being worked at Ardwick and made into an hydraulic mortar. The first limestone layer on the eastern side of the bridge has the appearance of a breccia cemented by carbonate of lime. Some of the beds are fossiliferous. The dip is 20 degrees. A remarkable point in connection

with the section is the occurrence of numerous blocks of the limestone mingled with the overlying clay on the eastern side of the section, none being found to the west. A careful search was made for fragments of Permian or New Red Sandstone rocks which may have been carried in the same direction, but none were noticed.

Dr. HODGKINSON made a communication on "Microscopical examination by mono-chromatic light, polarized light, etc."

Ordinary Meeting, October 21st, 1890.

Professor OSBORNE REYNOLDS, M.A., LL.D., F.R.S., Vice-President, in the Chair.

The thanks of the Society were voted to the donors of the books upon the table.

Professor H. B. DIXON, F.R.S., exhibited some of the nickel carbonic oxide recently described by Mr. Ludwig Mond, Dr. Langer, and Dr. Quincke, referred to at the previous meeting. The liquid is extremely volatile, and Mr. DIXON showed the effect of the vapour on a Bunsen-burner flame; he also exhibited nickel deposited from the vapour on a glass tube. It was pointed out that the discovery may lead to both new methods of research and more accurate determinations of the physical constants of nickel and cobalt.

Professor W. C. WILLIAMSON, F.R.S., referred to a communication which he had received from the Berg-Akademie of Berlin, giving details of the discorvery of four Stigmarian trees similar to the huge specimen in the Owens

College Museum, but smaller. The German specimens were found in collieries near Osnabrück. Two only were preserved, one of which is in the Osnabrück Museum, while the other has been placed in the museum of the Berg-Akademie. The longest root of the German specimens measures 13ft., while the longest root of the Owens College specimen measures nearly 21ft. The diameter of the stem of the latter is 4ft. against 2ft. that of the former. But while the Owens College specimen of an older tree has no cortical markings, the specimen in Berlin has markings showing where the vascular bundles passed through the bark to the leaves. The German specimens afford further evidence that the plants were Lepidodendroid. The dichotomous structure of the roots is clearly shown.

Mr. CHARLES H. LEES, M.Sc., read a paper "On a method of determining the Thermal Conductivity of bad conductors, with the results of experiments on Flint and Crown Glass." Mr. LEES referred to experiments by Professor Kundt, of Strassburg, apparently showing that in certain metals the refractive index is, roughly speaking, inversely proportional to the electric and thermal conductivities. Mr. LEES instituted the series of experiments described in order to see whether the same holds good as regards other substances. The results obtained for glass appeared to support Professor Kundt's result, that the thermal conductivity is proportional to the velocity of light in the substance experimented on.—A discussion ensued, in which Mr. C. N. ADAMS, Professor SCHUSTER, Mr. WILLIAM THOMSON, and Professor REYNOLDS took part. Professor SCHUSTER, while admitting the value of experiments so carefully carried out as those described by Mr. LEES, expressed doubt as to whether what was taken as the refractive index of Professor Kundt's metallic prisms could be safely regarded as corresponding to the refractive index of a glass prism.

General Meeting, November 4th, 1890.

EDWARD SCHUNCK, Ph.D., F.R.S., F.C.S., President, in the Chair.

Mr. EDWARD SIDEBOTHAM, Bowdon; Mr. MAURICE JULIUS LANGDON, Ph.D. (Munich), Manchester; Mr. WALTER TAYLOR, A.M.I.C.E., Flixton; and Mr. R. HAMMERSLEY HEENAN, Manchester, were elected ordinary members of the Society.

Ordinary Meeting, November 4th, 1890.

EDWARD SCHUNCK, Ph.D., F.R.S., F.C.S., President in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

The PRESIDENT referred to the loss sustained by the Society through the death of Mr. JAMES PLATT HOLDEN, who was elected a member in 1846.

Mr. WILLIAM BROCKBANK, F.L.S., F.G.S., exhibited *Estheria Minuta*, var. *Brodieana* of Prof. Rupert Jones, F.R.S., discovered by Mr. C. E. de Rance, F.G.S., in the Lower Keuper sandstone of Alderley Edge, and read the following note on the subject:—

"The occurrence of this fossil is new to the Triassic sandstones of Britain in Cheshire. These have been largely exposed of late in the cuttings of the new Ship Canal and the railway at Fallowfield, but at Fallowfield a diligent search was made for fossils, without result, in the

numerous lenticular pockets which occur in the Middle-Bunter sandstones, and which are filled with hematite red, fine, sandy marls. The pockets nearly always contained one or more pebbles of quartzite, which were stained and coated with hematite. A great many of these pockets were very carefully examined by Mr. de Rance and myself, but no fossils were found, although we felt, before the discovery at Alderley, that they were likely to occur in such a position. The *Estheriæ* now exhibited were found in similar lenticular-shaped, clay-filled patches in the Lower Keuper sandstones of Alderley Edge; and the discovery is one of great interest at this time; no *Estheriæ* having previously been found in the Triassic series below those occurring in the Keuper marls. Mr. de Rance has sent specimens to the Geological Survey Museum in Jermyn-street and to the British Museum. The specimens have been examined by Professor Rupert Jones, who has written to Mr. de Rance that they are almost fac-similes of Fig. 9, Pl. 12, of the 'Monograph of Fossil Estheriæ' (*Palæon. Soc.*, 1862). Professor Jones states that the form had not previously been found in England out of the Rhætic, in which it was discovered by the Rev. P. B. Brodie, F.G.S., at Wainlode Cliff, Gloucestershire. The type form, *Estheria minuta*, found high up in the Keuper marls of the Midland Counties, has not occurred yet in the Lower Keuper sandstone of Britain or the Continent."

Mr. WILLIAM BROCKBANK, F.L.S., F.G.S., also exhibited a cutting, 12 feet in length, bearing numerous tubers and flowers, of *Boussingaultia baselloides*, Humb. et Kunth, which he had cut from a plant which he had had growing for about six years, and which had only flowered in the preceding month, when Mr. Leo H. Grindon named it for him. He had received the plant from Australia, but it was really a native of South America, and was rarely seen in the neighbourhood of Manchester. Mr. CHARLES BAILEY

observed that the plant was a native of the Andes, and that only three members of the genus were known, all South American, Mexican, or belonging to the Galapagos archipelago. It was figured in the *Botanical Magazine* (plate 3620) more than 50 years ago. It was named by Humboldt and Kunth, in honour of the celebrated chemist Boussingault, whose researches in botanical physiology and chemical agriculture are the foundation of much of the successful practice of modern agriculturists and horticulturists. The plant is often to be seen in the court-yards of Parisian and other French houses, but as it flowers there in late September or October it does not attract the special attention of the summer tourist. It is grown for its profuse flowering racemes of whitish flowers, the odour of which is not unlike that of the common meadow-sweet or hawthorn. It is a climbing plant, with very slender branches and large glossy heart-shaped leaves, and being of rapid growth it soon covers over trellis-work, balconies, and the like with its convolvulus-like leaves, and its graceful spikes of flowers. The least frost cuts it down, but with a little top covering it stands the winters of the south of France; about Paris the gardeners keep it in caves or other cover as soon as frost sets in. It has frequently flowered in this country when grown in the open ground with a favourable aspect, but it comes on best in the greenhouse. The special peculiarity of the plant is its habit of producing tubers in the axils of its leaves; these tubers have only a fragile attachment to the stem and a mechanical shock will often cause them to fall. A healthy plant will have many fallen tubers at its base, each one of which is capable of originating an entirely new plant. Some of our common British plants produce analogous organs; the pilewort (*Ranunculus Ficaria*, L.) frequently produces them, and such plants are to be collected in the Bollin Valley, near

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experiments by Mr. Thomas, of Jesus Lane, Cambridge, the plan of insulation with asbestos being that described by Mr. Griffiths in a communication to the Royal Society, read June 19th, 1890. For lower temperature thermometers Mr. Griffiths has recently used anthracene as the insulating material. (See *Reports of Section A of the British Association at Leeds.*) Mr. GEE has made with them a number of determinations of melting points and of the resistance of fused salts at different temperatures. Mr. BROCKBANK remarked that a thermometer to be trusted in measuring the temperature of a blast furnace was much needed.

Dr. SCHUNCK called attention to the new compound of nitrogen, which seems to act as an acid, instead of being a base or neutral. Dr. SCHUNCK also remarked on the new method of making indigo, which he described as comparatively simple, and one that seemed likely to lead to important results. Dr. BOTTOMLEY and Mr. FRANCIS JONES took part in the discussion.

Mr. GWYTHER called attention to the discovery in Canada of a large deposit of nickel, and pointed out the value of such a deposit, if it could, by lowering the price and increasing the amount, be brought into general commercial use. Mr. FARADAY inquired, with special reference to the gold and silver monetary controversy, whether chemists or physicists regarded any change in the order of rarity of the metals, or in their approximate quantitative proportions in nature, as at all probable?

On the determination of the Thermal Conductivities of bad conductors. By Charles H. Lees, M.Sc., Bishop Berkeley Fellow of Owens College. Communicated by R. F. Gwyther, M.A.

(*Received December 2nd, 1890.*)

The experiments of Senarmont and others* have shewn that anisotropic bodies possess different thermal conductivities in different directions, and that in the majority of transparent bodies the conductivity in any direction increases as the index of refraction of light in that direction diminishes. The methods by which these results have been obtained, differ little from that of Senarmont, which depended on the melting round a central heated point, of a thin layer of wax previously spread over the surface of a crystal. In general, the area melted is an ellipse, the ratio of the axes of which is equal to the square root of the ratio of the conductivities along them. Such methods, therefore, give no information with respect to the absolute values of the conductivities, and a glance at the different results obtained in successive experiments on the same crystal shews that even the comparative values cannot be trusted except as rough approximations.

The recent determination by Prof. Kundt of the indices of refraction† of a number of metals, and the fact that he finds they stand in the same order with respect to

* References may be found in any text book, *e.g.*, Wüllner, Lehrbuch der *Experimentalphysik* iii., p. 310.

† Strictly we can only speak of an index of refraction of a substance when Snell's Law $\sin i/\sin r = \text{constant}$, is obeyed. Kundt therefore defines the index for a metal as the limit when $i = 0$ of $\sin i \sin r$. The recent experiments of Du Bois and Rubens (*Phil. Mag.* [5] XXX. 365) have shown that for iron, cobalt, and nickel, Snell's Law is approximately true, but that there is considerable deviation from it in silver and gold.

velocity of transmission of light and thermal conductivity, make it important to determine the conductivities of crystals in different directions with greater accuracy and in absolute measure, in order to compare different crystals with each other. At the suggestion of Prof. Kundt, I commenced some time ago at Strasburg a series of experiments with this end in view. Although these experiments are not yet completed, I propose in this paper to give a short account of the methods tried and the approximate results obtained.

The desirableness of dealing with small pieces of crystals, and the impossibility of making temperature observations in the crystals themselves, point at once to placing a thin plate of a crystal between the ends of two bars of metal, one heated and the other cooled at the ends away from the plate, and observing the temperature along each bar. These observations, if the conductivity of the bars were known, would furnish data for a determination of the conductivity of the crystal.

Difficulties arise, however, from the imperfect nature of the contacts between metal and crystal. Lodge* proposed to improve them by inserting pads of tin-foil, but this I found not to answer. Eventually a metal which would amalgamate was used for the bars, and the amalgamated ends made contact extremely well.

As the bars and crystal lose heat by convection, conduction, and radiation to the surrounding air, a method (that of Ångström) was first tried which gives by one experiment both the internal and external conductivities. One end of the arrangement of bars and crystal was alternately heated for six minutes by steam and cooled for six minutes by water till the temperature throughout was a periodic function of the time.

* Prof. O. Lodge proposed in 1878 (*Phil. Mag.* [5] V. p. 110) to determine the conductivities of crystals by the above method, but I am not aware that he has published any results.

If

v = excess of temp. at point x over that of air.
q = area of section of bar.
p = perimeter of section of bar.
ρ = density.
c = specific heat
k = internal conductivity } supposed constant.
h = external conductivity supposed to follow Newton's law.

the equation to the motion of heat in the bar, the isothermal surfaces being supposed plane, is

$$c\rho\frac{\partial v}{\partial t} = k\frac{\partial^2 v}{\partial x^2} - \frac{p}{q}h.v. \qquad (1)$$

the steady periodic solution of which is :—

$$v = \phi(x) + \sum_{n=1}^{\infty} A_n e^{-\mu_n x}\cos 2\pi\left(\frac{t}{T} - \frac{x}{\lambda_n} + \alpha_n\right) \qquad (2)$$

where T = period, A, μ, λ are constants and

$$\left.\begin{aligned} k &= \frac{c\rho\lambda_n}{2\pi\mu_n}. \\ h &= \frac{c\rho}{2T}\left(\lambda_n\mu_n - \frac{4\pi^2}{\lambda_n\mu_n}\right) \end{aligned}\right\} \qquad (3)$$

From these equations it is evident that observations of temperatures at two points of one bar give λ_n and μ_n and thence the internal and external conductivities of the bar, and observations at two points on opposite sides of the crystal plate and as close as possible to it, give similarly the conductivities of the crystal.

Temperatures were determined by three thermo-electric couples of iron and German silver wire soldered into the bars near the crystal, and in circuit with a galvanometer. By taking two additional thermo-junctions in the metal bar, the solution (2) was tested, and found not to represent the variation of temperature throughout the bar. I have since shown that this is to a great extent due to the great increase of k with

the temperature,* and that Ångström's solution (2) can only be taken as a rough approximation to the actual variation of temperature throughout the bar.

To get rid of this difficulty of the variation of k with the temperature, and at the same time to do away with the necessity for a knowledge of the values of c and ρ for the crystal, I began experiments with the bars and crystal packed in a cylinder of saw-dust, and used only the "steady state." The bars were of brass, 2 cms. diam. and 26 cms. long. The ends of each bar were amalgamated, and along the curved surface four thermo-junctions of iron and brass wire were soldered, two being as near the ends as possible. The two bars were held in position within a vertical paper cylinder 8 cm. diam. by means of six set-screws, which enabled the two amalgamated surfaces, between which the crystal disc was to come, to be set parallel. After putting in the crystal, the space between the bars and paper cylinder was packed with saw-dust, the screws withdrawn, and contacts made at top and bottom with a water and a steam can respectively. The ends of the wires from the thermo-junctions came outside the paper cylinder and could be put in succession in circuit with a galvanometer. Observations of deflections of the galvanometer and a previous determination of the constants of the junctions, give the temperatures at eight points of the bars, and from these the values of dv/dx below and above the crystal respectively can be calculated. These, combined with a knowledge of the conductivity k of the brass bar, give the flow of heat into and out of the crystal disc respectively through its plane surfaces. From the eight observations of temperature, the temperatures of

* It is evident, moreover, that the solution (2) can only apply to a bar of infinite length heated and cooled at one end. For a finite bar, and especially for the case of a bad conductor interposed between two lengths of bar, it is necessary to add to the expression (2) a corresponding expression in which the sign of x is altered. This makes the calculation of k and h much more complicated.

the two surfaces of the crystal can also be found.* We thus have a determination of the conductivity of the crystal in a direction parallel to the axis of the disc by a method which follows very closely the definition of conductivity. If the saw-dust were an absolute non-conductor the method would agree exactly with the definition.

In the above the isothermal surfaces have been assumed plane and perpendicular to the axis of the bar, but in the experiments the temperature at five points of the outer cylinder were also determined, so that each experiment gives sufficient data for determining the distribution of heat throughout the whole space within the outer cylinder. I did not consider, however, that the accuracy obtained in the observations would warrant the carrying out of the calculations on these rigid lines, especially as no tables exist of one of the functions which enter into the calculation.†

The conductivity of the brass bar was determined by Forbes's method, with the modifications suggested by me in a previous paper.‡ Two experiments are necessary, one determining the outer and the other the relation between the outer and inner conductivity.

Cooling Experiments to determine the Outer Conductivity.

In these experiments one of the bars used in the crystal apparatus is heated to 100° in an air bath and then allowed to cool in air, the temperature being observed by thermo-junctions soldered to the middle of the bar.

Writing m for the mass of the bar cooled, s its surface,

* The main features only of the calculations are entered into here. In the actual calculation corrections are applied for the thin layer of mercury between the crystal and the bar, for the variation of $dv\,dx$ within the crystal, &c., the amount of these corrections being determined by special experiments.

† I refer to the Bessel's function of the second kind and zero order for unreal values of the argument.

‡ *Phil. Mag.* (5) xxviii. p. 442.

and assuming the temperature of the bar to be constant throughout, we can put (1) in the form

$$cm\frac{\delta v}{\delta t} = -sf(v)$$

where $f(v)$ is a function of v determined by experiment to be of the form hv^n where h and n are constants. If the temperature of the surrounding air is not constant the equation takes the form

$$cm\frac{\delta v}{\delta t} = -sh(v - V)^n$$

where V is the temperature of the air.
Multiplying both sides of this equation by dt and integrating we have

$$v - v_0 = -\frac{sh}{cm}\int_{t_0}^{t} (v - V)^n dt$$

where v_0 is the temperature at time t_0.

The following table gives the mean result of three experiments :—

TABLE I.

Minutes t.	v	V	$(v-V)^{1\cdot11}$	$\int_{t=79}^{t}(v-V)^{1\cdot11}dt$	$\int_{t=79}^{t}(v-V)^{1\cdot11}dt/(v-v_{79})$
0	88·55°C	15·62°C	151·2	3281	MEANS.
2	82·50	15·51	136·9	2993	
4	77·08	15·48	124·1	2732	48·24
6	72·24	15·49	112·7	2495	
8	67·78	15·49	102·5	2280	
10	63·81	15·54	93·3	2084	
12	60·00	15·58	84·7	1906	
14	56·77	15·58	77·5	1744	48·08
16	53·78	15·56	71·0	1595	
18	50·93	15·58	64·8	1460	
20	48·29	15·59	59·1	1336	
22	45·92	15·59	54·2	1223	
24	43·84	15·61	49·8	1119	48·05
26	41·79	15·63	45·6	1023	
28	39·95	15·64	41·8	936	
30	38·25	15·64	38·4	855·5	
32	36·79	15·62	35·6	781·5	
34	35·29	15·59	32·7	713·2	48·22
36	34·00	15·59	30·2	650·3	
38	32·68	15·55	27·8	592·3	
40	31·65	15·52	25·9	538·7	
42	30·59	15·50	23·9	488·9	
44	29·64	15·44	22·3	442·7	48·63
46	28·72	15·40	20·7	399·7	
48	27·76	15·44	18·9	360·2	
50	27·05	15·40	17·7	323·6	
53	26·17	15·42	15·9	273·3	48·38
56	25·14	15·41	14·3	228·0	
59	24·31	15·47	12·8	187·3	
64	23·20	15·52	10·9	128·1	
69	22·13	15·53	9·1	78·2	47·79
74	21·24	15·47	7·8	36·0	
79	20·50	15·46	6·6		

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From this it is seen that the cooling is represented with great accuracy by the above equation if $n = 1{\cdot}17$, the specific heat of the bar being supposed constant.

We have

$$\frac{mc}{sh} = 48{\cdot}18 \text{ per minute.}$$

Now

$$m = 644 \text{ grams.}$$
$$c = {\cdot}092$$
$$s = 160 \text{ sq. cms.}$$

Hence $h = {\cdot}000{,}128$ calorics per sq. cm. per second for 1°C excess.

STATICAL EXPERIMENTS TO DETERMINE k.

In these experiments the uncut bar of about one metre length is heated at one end, and the temperature along it in the "steady state" determined by means of thermo-junctions.

The equation (1) reduces for this experiment to the form

$$kq\frac{d}{dx}\left(k_v\frac{dv}{dx}\right) = \frac{p}{m}.h(v - V)^n.$$

where k represents the conductivity at a temperature v; and V is the temperature of the air under any section.

Multiplying through by dx and integrating we have

$$q.\left/ k_v\frac{dv}{dx}\right/_{x_2}^{x_1} = \int_{x_2}^{x_1} ph.(v - V)^n dx,$$

where x_1 x_2 are the coordinates of any two points on the bar.

The following table gives the mean of three experiments, the integration being performed by mechanical quadrature.

TABLE II.

x	v	V	$(v-V)^{1\cdot11}$	$\int_0^x (v-V)^{1\cdot11}dx$	$\frac{dv}{dx}$	$\int_0^x (v-V)^{1\cdot11}dx+41$	$\left(\int_0^x (v-V)^{1\cdot11}dx+41\right)\frac{dv}{dx}$	k_v
0	17·44° C	16·05° C	1·47		(·040)	41·0	985	(·26)
23·90	18·61	16·17	2·84	46·6	·0887	87·6	987	·262
45·73	21·34	16·20	6·79	145·5	·1888	186·5	988	·262
64·50	25·91	16·37	14·00	328·7	·3749	369·7	986	·261
79·98	33·39	16·50	26·69	628·5	·7084	669·5	945	·251
92·36	44·40	16·61	48·90	1080·2	1·228	1121·2	913	·242
107·15	57·32	16·67	76·31	1621·5	1·784	1662·5	932	·247
108·42	72·21	16·71	109·85	2243·1	(2·308)	2284·1	990	(·265)

The first and last numbers in the sixth and ninth columns are uncertain, as dv/dx at the ends of the curve x, v, can only be determined approximately.

From the approximate value of k, which can be obtained from the 5th and 6th column of this table, the approximate value of $qk_v\frac{dv}{dx}$ when $x=0$ is determined to be 41. Hence column 7 is calculated; and the numbers in it are

$$=\left(qk.\frac{dv}{dx}\right)_{x=0}+\int_0^x ph(v-V)^n dx.$$

The numbers in the column headed k_v are calculated from the equation

$$k_v=\frac{ph\{\int_0^x (v-V)^{1\cdot17}dx+41\}}{q\frac{dv}{dx}}=\cdot000,265\frac{\int_0^x (v-V)^{1\cdot17}dx+41}{\frac{dv}{dx}}$$

CONDUCTIVITIES OF CROWN AND FLINT GLASS.

Taking ·250 as the conductivity of the brass bars the following results are deduced from several experiments on crown and flint glass discs, the temperatures in each disc being supposed represented by the equation $v=ax+bx^2$, the origin of x being taken at the cooler surface of the disc and the temperature of that surface being taken as zero.

Crown glass ·16 cm. thick.

x	v	$k_b\frac{dv}{dx}$
0	0	·222
·16	16·02	·250

$k_b\frac{dv}{dx}$ being the amount of heat which crosses a surface of contact of disc and bars, as calculated from the observations of temperatures in the bars

From this I find k for crown glass = ·00235.

Flint glass ·177 cm. thick.

x	v	$k_v \frac{dv}{dx}$
0	0	·211
·177	18·98	·234

From this I find k for flint glass = ·00208.

Taking the index of refraction of crown glass as about 1·5, and of flint glass as about 1·6, it is seen that the thermal conductivity of glass increases as its index of refraction diminishes, as Kundt found to be the case in metals.

The numbers ·00235 and ·00208 may be relied on to a greater degree relatively to each other than absolutely, owing to change of Electromotive Force of the thermo-junctions, produced by an unavoidable straining of the wires in packing the saw-dust between the bars and the outer cylinder. On this account the apparatus has been modified, and I am at present engaged in re-determining the conductivities of the glass discs used in the above experiments, and in determining the conductivities of quartz and Iceland spar in different directions. The results of these experiments I hope shortly to communicate to the Society.

[*Microscopical and Natural History Section.*]

Ordinary Meeting, November 10th, 1890.

ALEX. HODGKINSON, M.B., B.Sc., President of the Section, in the Chair.

Mr. THOS. ROGERS exhibited three fossil *Brachiopoda*, viz.:—*Athyris Camillosa*, *Athyris plano-sulcata*, and *Spinifera striata*, showing the internal structure laid bare by the Rev. Norman Glass's process of preparation.

Mr. CHAS. BAILEY, F.L.S., exhibited a series of European specimens of the genus *Pedicularis*, and for comparison with these Mr. J. COSMO MELVILL sent a number of extra-european species of the same genus. Mr. BAILEY pointed out that the peculiarity of their geographical position is the large number of endemic species, as four-fifths of the whole occupy restricted areas of the surface of the globe. Thus Maximowicz has shown that no less than sixty-seven species are confined to China, but this figure is being increased by the researches of French botanists in Yunnan; Europe has thirty-three endemic species; India thirty-three; Siberia and Turkestan twenty-nine; America twenty-two; Western Asia fourteen; and Japan five. Whilst there is great superficial resemblance between individual species, there is little tendency to gradation between them, such as is seen in *Hieracium*, *Rosa*, *Rubus*, *Salix*, and other Polymorphic genera. Analytical botanists, like Jordain and Boreau, have not created a single species out of any variations in the fifteen species which are found in France—a significant fact when it is remembered what this school of botanists have made out of the Linnean *Draba verna*. The fixity of the species in *Pedicularis* is brought into strong relief by the consideration of the circumstance, that botanists have

not sensibly changed the mode of grouping and separating the species which was adopted by Stevens, the first serious monographer of the genus, who so recently as 1822 described only forty-nine species then known to science. The names which he then gave to some of the groups may be altered, but the relative values of the characters on which they are based remain without any great modification, and the classification which Stevens proposed for less than fifty species is found equally applicable to five or six times that number. Mr. BAILEY showed a set of diagrams demonstrating the striking differences which exist between allied European species in the size, form, colouration, and sculpturing of the seeds. The life history of these plants is but little known, nor is it settled whether the two ubiquitous British species are annual, or perennial, or both. There is little doubt, however, that they are semi-parasitic in habit, living to some extent on the roots of grasses and other plants, and attention was drawn to the sucker—the organ by means of which they attach themselves to the subterranean organs of other living plants.

[*Physical and Mathematical Section.*]

Ordinary Meeting, November 12th, 1890.

WILLIAM THOMSON, F.R.S. Ed., F.C.S., F.I.C., Vice-President of the Section, in the Chair.

Mr. WILLIAM THOMSON, F.R.S. Ed., made a communication on the influence of tobacco-smoke in reproducing, after some hours, the smell and taste of chloride of sulphur. Mr. THOMSON stated that some time ago he visited an india-rubber factory, in which vulcanizing by the cold process was carried on by the use of a mixture of chloride of sulphur and bisulphide of carbon. This mixture has a pungent and disagreeable smell. An hour and a half after leaving the works, on smoking a cigar, he again noticed the smell and pungency of the chloride of sulphur at each inhalation of smoke. He then learned from the owner of the works that when he himself visited, for any length of time, the cold vulcanizing room he could not smoke on that day, because of the disagreeable odour of the chloride of sulphur, which was produced by the smoke. Mr. THOMSON had that day visited the works early, and, two hours afterwards, after luncheon, while smoking a cigar which he had not in his possession at the works, found that the same pungent effect was produced, although he breathed apparently very little of the substance, which had not caused him to experience in the interval any unpleasant effect.

Mr. THOMSON also communicated to the Section the results of some experiments he had recently made on the action of different substances on india-rubber. He employed fine layers of india-rubber attached to paper, and kept at a temperature of 130° (Fahr.). Very minute quantities of copper salts applied, in solution or mixed with water, and

allowed to dry on the rubber, soon destroyed its elasticity. Rubber is rapidly destroyed by oxidation; but the Chromates and even Chromic acid, powerful oxidising agents, regarded by chemists generally as fatal to rubber, had, he found, little or no effect on it. The oxides and salts of manganese had an injurious, and nitrate of silver a most injurious, influence on rubber. There are many other salts which have more or less destructive influences, but the above are a few of the most curious examples.

Ordinary Meeting, November 18th, 1890.

EDWARD SCHUNCK, Ph.D., F.R.S., F.C.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

The following note from Mr. WILLIAM BROCKBANK, F.L.S., F.G.S., was read:—

"At the last meeting of the Society I communicated the interesting discovery, by Mr. de Rance, of *Estheria minuta*, var. *Brodieana*, at Alderley Edge. Mr. de Rance has since pointed out to me that Professor Rupert Jones states that the variety *Brodieana* occurs in the 'Lettenkohl' of the Baden Trias. This formation is on the lowest horizon of the German Keuper, as is the Cheshire Keuper 'Building Stone,' and in this relation it is of great interest to note that this is the formation in which the oldest known mammal, *Microlestis*, occurs on the Continent, the presence of which in England was first made known, by Professor Boyd Dawkins, in the Rhætics of the West of England.

The small mammal and the minute crustacean occurring both above and below the Keuper marls, may it not be hoped that the mammal may be added to the fossil fauna of Cheshire? The discovery points to a recurrence of conditions, and supports the view expressed in 1847, by the late Professor Edward Forbes, that the beds now called Rhætic are really part of the Trias. This view was also held by the late Sir Philip Egerton, on the evidence of the fish remains."

Mr. HENRY H. HOWORTH, M.P., F.S.A., read an elaborate paper on the history and present position of the theory of glacier motion, in which, after reviewing the various hypotheses which have been put forward to account for the phenomena, he arrived at the conclusion that Forbes's theory is in the main the right one, and that glaciers move down the valleys much as a river flows. A discussion ensued, in which Dr. BOTTOMLEY, Professor OSBORNE REYNOLDS, Professor SCHUSTER, Professor DIXON, and Mr. HARRY GRIMSHAW took part, the general conclusion being that while glaciers are viscous and move by gravity, the various phenomena are explainable by a combination of the several physical conditions on which the various theories have been based. Professor REYNOLDS supposed that all who have lived in the neighbourhood of a glacier must have known that it flowed down the valley, and there is no doubt that it flows under deformation, by gravity; and any one may have noticed from the bending of ice at the edge of a pond that ice is plastic. Dr. SCHUSTER agreed in general with Professor REYNOLDS. In his own observations on glaciers he had been more struck by the irregularities of the motion than by the regularity—and, in fact, the motion is very uneven, and only regular on the average. With regard to the origin of the curious glacier crystals, it was urged that the difficulties are largely those of crystal formation generally. In this view Dr. BOTTOMLEY

and Mr. GRIMSHAW agreed. Professor DIXON thought there was pressure in a glacier much greater than that due to the superincumbent ice. Professor REYNOLDS said that at every crack heard in a glacier there was at some place a pressure of over thirty atmospheres. Any obstruction causes a great local intensity of pressure.

Ordinary Meeting, December 2nd, 1890.

EDWARD SCHUNCK, Ph.D., F.R.S., F.C.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Mr. H. D. POCHIN, F.C.S., alluded to the exceptionally heavy rainfall in the Conway valley during the previous month, and a discussion on the recent heavy fall also in this district ensued, in which Mr. Alderman BAILEY, Mr. C. E. DE RANCE, F.G.S., and others took part.

Professor W. C. WILLIAMSON, LL.D., F.R.S., read the introduction to the first part of a "General, Morphological, and Histological Index" to his memoirs on the Fossil Plants of the Coal Measures which he is compiling, at the request of the Council, to enable palæo-botanists to refer to any details of importance in the long series of memoirs in question. The PRESIDENT and members expressed grateful appreciation of the value of this completion of Dr. WILLIAMSON'S long and arduous researches, and the author stated in reply that he had arranged for the transfer of his collection of illustrative specimens to the Manchester Museum, now located at Owens College.

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Mr. WILLIAM BROCKBANK, F.L.S., F.G.S., exhibited a series of polished surfaces of the Levenshulme mottled limestones and thin sections of each group prepared for the microscope, and read a paper on "The *Entomostraca* and *Annelida* in the Levenshulme Mottled Limestones."

Mr. W. W. H. GEE, B.Sc., F.C.S., read a paper by himself, and Mr. H. L. TERRY, F.I.C., on "The Specific Heat of Non-conductors. Part I.—Caoutchouc."

[*Microscopical and Natural History Section.*]

Ordinary Meeting, December 8th, 1890.

ALEX. HODGKINSON, M.B., B.Sc., President of the Section, in the Chair.

Mr. ARNOLD UMFREVILLE HENN was elected an associate.

There were exhibited :—

By Mr. H. HYDE, a number of curious foreign fruits; Mr. CHAS. BAILEY, F.L.S., the cones of *Pinus pinea*, and the edible seeds taken from them; the PRESIDENT, a remarkable illustrated work on Botany, Natural History, and Petrology, dated 1492, in which were described and figured a number of strange creatures still unknown to science; and by Mr. J. COSMO MELVILL, F.L.S., a series of very beautiful *Coleoptera* of the genus *Carabus*, section *Ceroglossus*, from Chili and Patagonia.

Mr. J. COSMO MELVILL, F.L.S., read a paper describing *Drosera intermedia* (Hague) var. *subcaulescens*, from Wybunbury Bog, Cheshire, illustrated by a drawing, and exhibited specimens of this and other *Droseræ* for comparison.

Mr. MARK STIRRUP, F.G.S., read a letter from one of the associates of the section, Mr. W. LADD TORRANCE, Java, describing some experiences when hunting for natural history and geological specimens; and exhibited a photograph of a range of volcanoes in Java, with a plain of sand at their base, and a number of so-called "lucky stones," which Mr. TORRANCE had sent home.

Ordinary Meeting, December 16th, 1890.

EDWARD SCHUNCK, Ph.D., F.R.S., F.C.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Professor OSBORNE REYNOLDS, LL.D., F.R.S., introduced the subject of the low temperatures lately registered, and warned observers who use spirit thermometers that they frequently show too low a temperature through the spirit being present at the top of the thermometer.

Mr. H. H. HOWORTH, M.P., F.S.A., attempted to deduce, from a path of migratory birds, the result that the mammoth and animals living with it may have reached Italy from Dalmatia by an ancient coastline.

Professor H. B. DIXON, F.R.S., discussed the authorship of the law of equal dilation of gases known on the Continent as that of Gay Lussac, and in England and America as that of Charles. Nothing seems to have been published by Charles, but his work is referred to in the paper by Gay Lussac, read February 1st, 1802, and published in the *Annales de Chimie*, August, 1802. Dr. Dalton read before the Society a long paper, entitled "Experimental essays on the constitution of mixed gases," on October 2, 1801, which was published in Vol. V., Part II., of its *Memoirs* in 1802, in which paper experiments with air and other gases are described, from which the author concludes that "*all elastic fluids under the same pressure expand equally by heat.*" Professor DIXON remarked that the method and apparatus described in text books as that of Gay Lussac bear no resemblance to those given in his papers, and expressed a desire to learn the origin of the method usually described.

Dr. JAMES BOTTOMLEY, B.A., F.C.S., read a paper on

"The intensity of transmitted light when the coefficient of transmission is a function of the time."

Mr. WILLIAM BROCKBANK, F.L.S., F.G.S., and Mr. C. E. DE RANCE, F.G.S., read the first part of a paper on "The Geological Section exposed by the railway cutting at Levenshulme." The paper was illustrated by an elaborate coloured chart of the whole section drawn to scale. A discussion ensued, in which Mr. PERCY F. KENDALL, Mr. J. W. GRAY, and Dr. G. H. BAILEY took part.

Mr. WILLIAM THOMSON, F.R.S. Ed., F.C.S., read a paper by himself and Mr. FREDERICK LEWIS on "The action of various chemical compounds and metals on india-rubber," and exhibited samples illustrating the remarkably deleterious influence of copper salts.

On the Specific Heat of Non-conductors. Part I: Caoutchouc. By W. W. Haldane Gee, B.Sc., F.C.S., and Hubert L. Terry, F.I.C.

(*Received December 2nd, 1890.*)

Comparatively few determinations have been made of the specific heat of non-conductors, and, since a knowledge of this constant has become of some technical importance, we have made a number of experiments with different substances. The present paper will be devoted to Caoutchouc.

Fine Para rubber $\frac{1}{114}^{th}$ of an inch thick was generally used, and the following figures represent fairly its composition:—

Caoutchouc	96·83
Resin	1·25
Water	1·77
Soap, etc.	0·15
	100·00

Since the water is driven off when the rubber is heated to 100° C. the substance actually used contained about 98·5% of caoutchouc and about 1·3% of a material whose specific heat would be little different from that of caoutchouc. It may be considered then that we have been dealing with pure caoutchouc of the formula $(C_{10}H_{16})x$. For the supply of material and for assistance generally we are much indebted to Messrs. Chas. Macintosh and Co., Limited, of Manchester.

As Regnault's method of mixtures was employed, not much description of the process is necessary. At first sight the determination presents the difficulty that the rubber being an exceedingly bad conductor of heat, the

time of the mixture attaining its maximum temperature will be prolonged, and the correction for cooling large and its calculation uncertain. We find, however, by applying the correction formulæ, that the error from this source becomes unimportant, and certainly less than the errors incident to the variation in the composition of the substance, or to the difficulty of ascertaining its exact temperature when heated.

Description of Apparatus.

Calorimeter.

This was made of thin hard-rolled brass 62^{mm} diam. and 152^{mm} long. It was enclosed within an outer zinc can 120^{mm} diam. and 188^{mm} in depth, separated by corks. This zinc can was soldered to an outer can filled with water 200^{mm} diam. and 255^{mm} deep. Finally, the whole was enclosed within a box packed with wool.

The outer can was provided with an annular stirrer, while the calorimeter had a smaller stirrer with a glass handle. A baize curtain divided the calorimeter from the heating apparatus.

Three different kinds of stirrers were used :—

(1) Perforated bucket of very thin sheet with a wooden handle. The roll of rubber was dropped into this.

(2) A glass handle was fixed to a zig-zag piece of brass which was fixed in the rubber.

(3) A thermometer was fixed in the centre of the roll of rubber.

In the latter two cases the stirrer was also in the heating vessel.

Heating Apparatus.

In the earlier experiments a steam oven, having a constant temperature of 98° C., was employed. The rubber

was enclosed in a wide test-tube plugged with cotton wool, and surrounded with a cloth. Later we used a steam-jacketed copper vessel, into which the test-tube fitted. The loss of material during the two hours' heating, starting with rubber exposed to a saturated atmosphere as tested by means of a hygrometer, amounted to 0·64 per cent.

Thermometers.

For the estimation of the temperature of the calorimeter two thermometers by Hicks were used :—

(1) No. 430296 had a range from 13° to 23° C. and was divided into 10^{ths}, each degree being about 25^{mm}.

Hence :—

$$1° = 25^{mm}$$
$$\cdot1° = 2\cdot5^{mm}$$
$$\cdot01° = \cdot25^{mm}$$

a quantity which was readily estimated with the naked eye.

(2) No. 430298.

$$1° = 35^{mm}$$
$$\cdot1 = 3\cdot5^{mm}$$
$$\text{each } \cdot1° = 5 \text{ parts} = \cdot05 = \cdot7^{mm}$$
$$\text{by estimation} = \cdot001 = \cdot14^{mm}.$$

For ascertaining the temperature of the hot rubber, a thermometer divided into degrees whose boiling point had been determined, was used.

The temperature of the enclosure was ascertained by means of a thermometer by Heintz, estimating to ·01°.

METHOD OF EXPERIMENT.

It was thought desirable to inter-roll the sheet of rubber with metallic foil, so as to hasten the time of cooling. This was accordingly done in most of the experiments, though we found afterwards that it lessened the time of mixture by no large amount. The foil employed through-

out the experiments, though sold as "tin" foil, was found to contain 80% of lead, and the determination of its specific heat gave as a mean of several estimations ·035, which value has been used in the calculations. In all cases the roll of rubber was completely encased in the foil, to prevent it from sticking to the test tube in the heating chamber.

About 20 grams of rubber as a rule were employed. This was inter-rolled with the foil and heated for about two hours in the chamber described, and then quickly transferred to the calorimeter, the rubber being easily slipped out of the glass tube.

The readings of the temperature of the calorimeter were noted at ½ minute intervals, the calorimeter being continuously stirred by hand.

Method of Calculation.

The following formula was used :—

$$s = \frac{W + K}{M} \cdot \frac{(\theta + C) - t}{T - (\theta + C)} - \frac{M'\sigma}{M}$$

where

M = mass of rubber.
M' = „ tinfoil.
W = „ water in calorimeter.
K = water equivalent of calorimeter, stirrer, and thermometer.
T = temperature of the rubber.
t = initial temperature of the water.
θ = final temperature of the water.
σ = specific heat of the foil.
s = „ rubber.

The value of C, which represents the loss due to cooling, may be obtained from one of the three following formulæ :—

Correction Formulæ.

(1) Regnault-Pfaundler (*Ann de Chim. et de Physique*, 4° Serie xi., p. 248, 1867.)

In this formula a graphic method of correction is employed, or the formula

$$C = nv + \frac{v^1 - v}{t^1 - t}\left(\Sigma^1_{n-1}\theta + \frac{\theta_0 + \theta_n}{2} - nt\right);$$

may be employed

where C is the quantity to be added to the observed maximum θ, which is taken as that temperature after which the difference of the successive readings remains constant;

v = rate of loss of temperature before the introduction of the hot body into the calorimeter, the mean temperature being t.

v' = the corresponding quantity after the introduction of the hot body, and when the rate of cooling becomes constant, the mean temperature being t^1;

$\theta_0\ \theta_1\ \theta_2 \ldots . \theta_n$ are the observed temperatures at the successive time intervals from the time of introducing the hot body to that of obtaining the maximum.

II. Pape (*Pogg. Ann.*, CXX, p. 579, 1863) gives finally

$$C = \frac{Vm - V_1 + Vm\lambda_1 T}{V - Vm - Vm\lambda_1 T} S_1;$$

in which

$$\lambda_1 = \frac{\log v_n - \log v_{n+1}}{\log e}$$

and

Vm = max temperature of Calorimeter.
V_1 = initial ,, ,,
V = temp. in heater.
T = time reaching maximum temperature.
S_1 = sp. ht. of fluid in Calorimeter.
v_n and v_{n+1} being successive temperatures during the period of regular cooling.

or, in its most approximate form, using the notation of the preceding formula,

$$C = n\theta_n \frac{\log \theta_m - \log \theta_{(m+1)}}{\log e}$$

where C is the quantity to be added to the actually-observed maximum θ attained in n time intervals; whilst θ_m and $\theta_{(m+1)}$ are successively observed temperatures in the period during which the cooling is regular.

III. Founded on the same differential equations used by Pape, Dr. Schuster has independently arrived at the following formula :—

$$C = \frac{\Delta\theta}{\Delta T} \cdot \frac{t_m - t_0}{t' - t_0}\left[\frac{\sigma_1}{\sigma_2} \cdot \frac{t_m - t_0}{t' - t_0} T' + \theta_m\right];$$

where $\Delta\theta$ is the fall of temp. in time ΔT during the period of steady cooling at the temperature t''.

t_m = maximum temperature reached in n time intervals.

t_0 = temperature of enclosure.

t' = observed temperature made after a lapse of time T' after the introduction of the hot body.

σ_1 and σ_2 = water values of the hot body and of the calorimeter and contents respectively.

θ'_m = time of reaching maximum.

We now give an example where the value of C is calculated by these three different formulæ :—

Mass of rubber ... = 38·70
„ foil ... = 21·3
„ water ... = 299·2
K = 3·67 + ·1 + ·5 = 4·3.

Mass of perforated brass holder used as stirrer 12·30.

t = 16°·97
t' = 21·62 Room temp. 17°·5
T = 99° after two hours' heating
$\theta - t$ = 22°
T − θ = 77°. Rise = 5°·03.

Thermometer in water to length of 3 inches.
The value of v was negligable.

Readings at ½ minute intervals.

0	reading	...	...	16·97 = θ_0
1	„	...	...	19·50 = θ_1
2	„	...	...	20·80 = θ_2
3	„	...	...	21·30 = θ_3
4	„	...	...	21·58 = θ_4
5	„	...	...	21·72 = θ_5
6	„	...	...	21·78 = θ_6
7	„	...	...	21.79 = θ_7

8	„	...	...	$21{\cdot}80 = \theta_9$
9	„	...	...	$21{\cdot}80 = \theta_n = \theta_9$
10	„	...	...	$21{\cdot}79$
14	„	...	...	$21{\cdot}71$
18	„	...	...	$21{\cdot}62$
20	„	...	...	$21{\cdot}58$
23	„	...	...	$21{\cdot}50 = \theta_m$
24	„	...	...	$21{\cdot}48 = \theta_{m+1}$
26	„	...	...	$21{\cdot}44$

Hence $v^1 = {\cdot}021$

Substituting these values in Pfaundler's formula we get, after simplifying,

$$C = \frac{{\cdot}021}{4{\cdot}65}\left(170{\cdot}2 + 19{\cdot}4 - 152{\cdot}7\right),$$

whence

$$C = {\cdot}17,$$

and substituting the above figures for the corresponding letters in Pape's formula we get

$$C = n\theta\frac{\log 21{\cdot}50 - \log 21{\cdot}48}{\log e},$$

whence

$$C = {\cdot}18$$

and by Schuster's formula we get

$$C = {\cdot}18.$$

We may here remark that this formula may be much simplified for our purpose by using the form

$$C = \frac{\Delta\theta}{\Delta T}\theta_n$$

as the rest of the formula generally only affects the third place of decimals.

If now we take ·2° as the value of C, putting this value into Regnault's equation, we get in the above example

$$x = \frac{299{\cdot}2 + 4{\cdot}3}{38{\cdot}7} \cdot \frac{(21{\cdot}8 + {\cdot}2) - 16{\cdot}97}{99 - (21{\cdot}8 + {\cdot}2)} - \frac{{\cdot}75}{38{\cdot}7}$$

$$x = {\cdot}5123 - {\cdot}0194$$

$$= {\cdot}493$$

That the correction is a very necessary one is seen if we calculate the above, ignoring C, when we obtain for x the value 0·471. About the same value for C, viz. ·2°, was obtained by Pape and Pfaundler, in a large series of experiments made on various earths and salts.

The results agree as well as can be expected, considering the nature of the substance. From the mean of the best experiments, shown in the following table, we obtain the figure ·480, which, with a possible variation of about 2%, may be considered as the specific heat of caoutchouc:—

SUMMARY OF RESULTS.

Caoutchouc.

Expt.	W.	K.	M.	M'e.	T.	*t.*	θ.	C.	*x.*
1.	298·07	6·1	23·94	·65	95·3	15·38	18·28	·12	·471
2.	298·46	6·1	18·82	·68	97·0	14·84	17·25	·16	·486
3.	295·4	5·1	18·35	1·01	98·2	14·32	16 84	·12	·474
4.	293·3	5·1	19·55	·85	98·5	15·01	17·74	·12	·483
5.	250·0	4·0	18·76	·44	98·0	16·35	19·18	·12	·484
6.	298·3	5·7	41·28	·06	99·0	18·72	23·39	·24	·478

EXPERIMENTS WITH OILS.

Some preliminary experiments have been made with the oils distilled from Caoutchouc. The caoutchouc was distilled in an iron retort, and the vapours condensed, then the liquid was shaken up with sulphuric acid, washed well with water, and re-distilled into different fractions. The lightest fraction—a pale yellow colour—was used, and as the oils are all polymeric, the same results would be obtained from all the fractions. The oils are isomeric with oil of turpentine,

whose specific heat is ·46. For calculating the specific heat some fragments of copper were heated and plunged into a known weight of the oil in a small calorimeter, the equation being now as follows

$$M\sigma(T-\theta) = (M^1x + k)(\theta - t)$$

and

$$x = \frac{M\sigma(T-\theta)}{M^1(\theta-t)} - \frac{k}{M^1}$$

where x = specific heat of oil.

M = mass of copper.
M^1 = mass of oil.
k = water equivalent of Calorimeter and stirrer.
σ = specific heat of the copper.

Temperatures denoted as before.

EXAMPLE—65 c.c. oil (sp. gr. = ·93) = 60·45 grm. Copper = 21·63. $T = 98·0$. $t = 18·45$. $\theta = 23·10$; whence by above formula we get

$$x = ·464.$$

The results obtained with vulcanized rubber in the form of sulphured cut sheet, were very similar to the pure rubber. There would be about 5% of sulphur present, of which the specific heat is ·202.

Some preliminary experiments made with gutta percha may also be recorded. This body, however, is difficult to deal with, as it changes its condition when heated, and again when plunged into the calorimeter, taking a very long time to reach the maximum temperature; gutta percha contains about 30% of two peculiar resins, to which its physical properties are chiefly due. We propose to give some figures concerning this and some allied substances on a future occasion.

On the Entomostraca and Annelida in the Levenshulme Mottled Limestones. By Wm. Brockbank, F.L.S., F.G.S.

(Received December 2nd, 1890.)

The British fossil *Entomostraca* from the Carboniferous formation have been described and figured, by Professor Rupert Jones and others, in the monograph issued by the Palæontographical Society in 1884.

All the figures there given were taken from fossils collected from the ironstones, limestones, and shales of the coal measures; chiefly from Carluke in Scotland. In one case 300 were found in a fish coprolite, and in another a large number were collected from the *débris* of decomposed limestone in a crevice traversing the rock, which had formed a subterranean water course; the limestone having been disintegrated by the solvent and mechanical action of the water. A few had been collected from the limestones of Settle and Bolland. I cannot, however, find any instance of microscopical examinations of limestone for *Entomostraca*, except a brief reference in the anniversary address of Mr. Sorby to the Geological Society in 1879. He there describes the microscopical structure of different limestones, and states that "the Burdie-house limestone is mainly composed of fine grained particles, the exact origin of which cannot be proved; but scattered through it are many *Entomostraca* with well-preserved structure." "The limestone of Ardwick, near Manchester," he says, "is very similar, but, in addition, it contains many entire or broken shells of *Microconchus*, with a well-preserved laminar structure, clearly showing that it is an annelid."

This paragraph was shewn to me by Mr. de Rance after I had completed the investigation of the structure of the

Levenshulme limestones. It will be seen that Mr. Sorby's description falls very short of the reality, if we are to take the Levenshulme limestones to represent those of Ardwick.

In communicating my first notes on the Levenshulme railway section to the Society last year, I made especial reference to the circular greenish spots which we had found everywhere present throughout the Triassic, Permian, and Carboniferous shales, sandstones, marls, and limestones, and which went by the name of "fish eyes." I stated that it would form a very interesting subject for enquiry, and I believed it would be found that these green spots were caused by the presence of *Entomostraca*. The "fish eyes" puzzle was ever before me, and I have been engaged upon it since. The solution of this question in the mottled limestones will, I think, govern all the rest; for they all appear to me to have similar conditions and appearances throughout the section from Trias to Coal Measures.

The whole of the Levenshulme limestones are more or less mottled. The basis colour is always grey, tinged pink with hematite; and this very sensitive pink colour is so readily discharged by an acid, that it forms a very delicate test if we can only follow out its indications. I very soon came to the conclusion that the cause of the greenish mottlings had a connection with animal life. In addition to the green mottlings, however, there were also smaller deep purple ones. A very simple examination of these tiny circles shewed them to be *Spirorbis* shells, cut through in all directions, this giving a dark purple mottling to every one of the limestones. In the upper beds the *Spirorbis* is less abundant, but in the middle beds the limestone is almost made up of its tiny shells. There is a polished sample of marble on the table from a bed in group No. 2, which shews about 300 *Spirorbis* shells in the square inch, giving the amazing number of 90,000 in one cubic inch. The mass of limestone is thus nearly built up of the remains of this

small annelid, which probably lived and died quietly near the spot. The *Spirorbis* has its like in the *Serpulæ* now living on our shores, feeding on seaweed.

Another mottling, and that to which the workman's name of "fish eye" more properly belongs, has a dark spot, or nucleus, in the centre of each green spot; the green fading gradually from the centre to the outside. The same thing occurs in all the shales as well as in the limestones, and especially so in the Permian red clays. I noticed in my workshop when the tables were covered with slabs of red marls, that the droppings of spiders and other large insects discharged the red colour and left a circular whitish mark permanently at the spot. This is, I believe, the explanation of the "fish eye" mottlings. They are produced by coprolites. There are examples of these upon the table. One of them shows in the centre of the dark nucleus a pink spot, which indicates organic matter,—as it is generally found hematite-stained in the limestone fossils. In the uppermost limestone, where the pink colour is very slight, coprolites occur as dull mottled circles, and in one of these is to be seen a small tooth, quite visible to the naked eye, and probably it will be found to have belonged to an amphibian. There can be little doubt about these coprolites, as a large number have been collected from the shales and marls, as well as these occurring in the limestones.

Returning to the simple green mottlings, which really present to us the greatest interest, it will be found that they are produced by organic remains, entombed in the limestones.

It is quite impossible to detect the delicate fossils which produced them in a limestone fracture, even with the most powerful lens. *Spirorbis* you see at once, and green mottling, but no trace of shells, so completely have they been absorbed into the stone.

I had a complete set of examples of the eight groups

into which these limestones may be classed polished by a marble mason—and there were then to be seen some indications of shells and coprolites, but still none of the *Entomostraca*. Next I had a set of thin sections of each of the limestone groups ground down and prepared for the microscope—a difficult operation with a limestone of a very fossiliferous and brecciated structure. The experiment was successful, and the result exceeded my expectations.

The following are my notes of a few examples of the eight or ten sections of limestones now produced:—

No. 3 group limestones shows the marble to be made up of small organisms, amongst which are beautiful sections of oval shells cut through at varying angles, some shewing the hinges and the overlapping of the bivalve shells. The thinness of the substance of the shells points to *Entomostraca*, and of these there are several forms present. One form appears to be *Cypridina Primoeva* (see Prof. Rupert Jones' monograph—"Entomostraca of the Coal measures"). Of this variety some have oval carapace valves, and some pyriform, and both these occur here. There are also many filiform objects, which may be either antennæ, or very small bones—some show a tubular structure under a high power, others have a cellular structure.

In another example from No. 3 group I note on the marble polished surface:—This is spotted all over with *Spirorbis* in great profusion, and with pale yellow circular markings, varying from half an inch diameter to tiny round spots, all indicating the presence of fossil organisms—some thousands to the cubic inch. The microscope reveals many interesting shells of *Entomostraca*, but having more substance and more oblate curves than in the former examples; the overlap of the valves is beautifully shewn (probably *Cytherella*). Many other small organisms are crowded into the field of view.

No. 4 group limestone has a very different appearance, both polished and microscopic, and shews the value of the microscope in examining one of these limestones. It does not take a good polish—has dark liver-coloured purple colour with yellow stain-lines and purple blotches—veins of Calcite run across it and the *Spirorbis* is rare, if at all present. It has a brecciated appearance, the fragments cemented with calc spar. It appears to have been formed in troubled waters, under disturbed circumstances. A thin section looks like a smear of hematite on the glass slide. Under the microscope it is seen to be made up of minute angular fragments everywhere iron stained. The shells of *Entomostraca* are here, but no two shells together, and many broken into fragments.

The 5th group limestone is again shewn to have an irregular constitution, being made up of curved lines of deposition and crowded with organic remains. *Entomostraca* are in profusion, and a fine "fish eye" centre is there with a red patch in it. The *Entomostraca* in this section are filled with crystals, probably of calc spar, which form very beautiful objects under the polariscope. The ¼in. power reveals curiously jointed tubular organisms, which may be serpulae, or small corals. In many respects this limestone differs from all the others. No more interesting object could be found for the polariscope, and it is absolutely crowded with organic remains, which are almost perfect. The Entomostracan which bears the name of *Daphnia Primæva*, here present, so precisely resembles the *Daphne* of our ponds that Mr. Brothers thought he was looking at that object in the microscope. The coprolite also is extremely interesting under the polariscope, as it shows great diversity of structures and small oval and curved objects, as if the food of the animals which dropped it had been these *Entomostraca*.

The 6th group limestones are again extremely in-

teresting, being much mottled in large blue and pink patches and teeming with organic remains. True fossil shells and bones occur in these limestones, and the microscopic view is crowded with small bone fragments, mixed up with *Entomostraca.*

The 7th group marbles have a dark purple colour, veined with black, yellow, and red. They are thickly spotted with *Spirorbis*, and under the microscope are crowded with bi-valve shells in true positions—there are also many of the tubular organism—the ¼in. power showing clearly the jointings and the central tube. A small shell with spiral centre occurs in this slide. The last group (No. 8) limestones are by far the most beautiful objects as marbles, the colour being of a lovely deep pink-grey, mottled with paler pink spots, and the polish is perfect. No microscopic slide has been prepared from this group, but one is in hand. The *Spirorbis* is present here, as it was in the first bed, and no doubt the *Entomostraca* will abound, as indicated by the mottling.

It will thus be seen that the microscope reveals to us the exact formation of these limestones, and that they abound in objects of extraordinary interest, in great profusion. The fact that chalk was made up of animal remains used to be cited as wonderful, but the variety and beauty of the organisms of which these Levenshulme limestones are made up are far more wonderful, and they open out a new field of research to the naturalist. The subject of their geological position, and all the details of the section which contains them, will shortly be laid before the Society by Mr. de Rance and myself.

General, Morphological, and Histological Index to the Author's Collective Memoirs on the Fossil Plants of the Coal Measures. Part I. By William Crawford Williamson, LL.D., F.R.S., &c., Foreign Member of the Royal Swedish Acad. Sc., and of the Royal Society of Göttingen.

(Received December 2nd, 1890.)

INTRODUCTION.

My systematic study of the organisation, external and internal, of the Fossil Plants of the Coal Measures, may be regarded as dating from 1851, in which year I published in the *Memoirs* of the Manchester Literary and Philosophical Society my paper "On the structure and affinities of the plants hitherto known as *Sternbergiæ*." Since the appearance of that memoir, a long series of similar publications have embodied the results of my continued researches. The magnitude of the subject, and the scantiness of our information respecting it, led me to adopt a definite line of procedure in publishing my results. Had it been possible, the best method would have been to have worked out whatever appeared to be discoverable about each form of plant, and then to have published the results in a series of special monographs.

But two difficulties attended the adoption of this method. Firstly, it was impossible to know, at any given point, whether or not I had obtained all discoverable information; and secondly, what were the chances of life being sufficiently prolonged, after such researches had been completed, to secure the publication of all the results. On the latter point I may express my conviction that even the year 1890 would not have seen the commencement of such a publica-

tion. I judged it wiser, therefore, to issue from time to time, memoirs which should contain whatever definite facts I succeeded in discovering about any of the Palæozoic types of vegetation; filling up the gaps in the record whenever further researches threw additional light on any of these types. But this method is also attended by some serious drawbacks. Even when published in successive volumes of the same journal, as in the case of the seventeen memoirs that have appeared in the *Philosophical Transactions* from 1871 to the present year 1890, the labour of hunting through numerous big volumes, and then piecing together my detached observations on each special plant, has become very serious. The difficulty becomes still more serious, when such memoirs have been published in different journals. Yet the number of new facts which I have recorded makes it indispensable that Palæo-botanists, who are my contemporaries, or who may be my successors in similar labours, should have those facts put as easily as possible within their reach. Living Palæontologists have already felt the difficulties to which I have referred; I have received many communications, both from my fellow-countrymen and from foreign correspondents, expressing the wish that I would prepare a collective index to the entire series of my Palæo-botanical publications. Having recognised the reasonableness of the demand, I now commence my response to it.

The Council of the Literary and Philosophical Society of Manchester having kindly invited me to prepare a series of such indexes for publication in their *Memoirs and Proceedings*, I lay before the Society the first part of such a series. Each succeeding part will embrace one or more of the great families of Palæozoic plants that have been the subjects of my researches. The descriptions and figures of each special organ of such plants will, as in my present contribution, be classified morphologically and histologically. Hence the

student will, in future, see, at a glance, where to find any information he requires respecting them. In my present contribution I have dealt with the large family of the *Calamariæ*, using that term in the comprehensive sense in which it has been adopted by my late friend Professor Weiss, of Berlin, and other recent writers on the subject.

In 1828 Adolphe Brongniart pointed out some of the affinities of the fossil Calamites with the living Equisetums. In his Classic "Prodrome d'une Histoire des Végétaux Fossiles," he included such *Calamites* as he was then acquainted with along with the true fossil Equisetums in the family *Equisetaceæ*. At the same time he left a large number of other plants, which we now know to be closely allied to the *Calamites*, in a group which he entitled "Vegetaux dont la classe est incertaine." In his "Tableau des genres des Végétaux fossiles," published in 1849, he still placed *some* of the Calamites in his family of "Equisétacées," but he transferred others to his "Troisième Embranchement Phanérogames Dicotylédones," grouping them along with some of his previous uncertain plants, such as *Sphenophyllum*, *Annularia*, *Hippurites*, *Astérophyllites*, and *Calamodendron*, in his "Sous-embranchement, Dicotyledones Gymnospermes; Famille des Astérophyllitées."

At an early period of my researches it became evident to me that these arrangements could not be accepted. I soon arrived at the conclusion that some, at least, of the above genera, along with others more recently established, must all be placed along with the Calamites in the Cryptogamic division of the vegetable kingdom, and that the recent Equisetums must also be included in the same division. The idea that first suggested itself was to include them all in the natural order *Equisetaceæ*;—making the living Equisetums the type of the order. But little reflection was needed to show me that more than this was required. It soon became evident that the Palæozoic forms represented

a comprehensive, highly organised, and ancient family, that, for a long period, held its head high in the vegetable kingdom, whilst the living Equisetums can only be regarded as subordinate and extremely degenerate descendants of that illustrious family of which they are now the sole representatives. Influenced by these views, I wrote in November, 1871, "After fairly weighing the evidence for and against the admission of the Calamites amongst the true *Equisetaceæ*, it appears to me that the reasons against doing so preponderate over those which favour such a course. To disturb the generally accepted definitions of a family of living plants for the sake of doing this seems to me unwise. I should therefore propose the recognition of a distinct family of *Calamitaceæ*, which, from their complex organisation, must necessarily stand high up in the great Cryptogamic division of the vegetable kingdom. ("On the Organisation of the Fossil Plants of the Coal Measures: Part I. Calamites." *Phil. Trans.*, 1871). My suggestion has now been acted upon in the wide recognition of such a family, but with the name of *Calamariæ*.

Some years ago the specimens in my cabinet had become so numerous that the convenience of reference made it necessary to arrange them numerically, as well as to prepare a systematic catalogue of them. This latter, in its present form, fills two large folio volumes, in which, not only the peculiarities of each numbered specimen are noted, but any special significance which those peculiarities seemed to possess are recorded. The attainment of these objects made another movement possible. In my Part XIII., published in 1887, in the four subsequent memoirs, and in my monograph on *Stigmaria ficoides*, published by the Palæontographical Society, I have attached to each figure and description the symbol C.N., along with the number which the specimen so described bears in the cabinet and folio catalogue. I believe that the adoption of this method will be found to

have a practical value. So far as the above six memoirs are concerned, any future students can know where to find the originals of the figures and descriptions therein published. The obvious advantages afforded by such a record of the location of some of my type-specimens made it desirable that the method should somehow or other be extended to the other specimens described in all my earlier memoirs, and the preparation of this Index has made the realisation of this object easy. Throughout its pages, the symbolic C.N., with its appropriate number, will be associated with nearly every figure and description quoted. Ere long, as is well known, my cabinet and its descriptive catalogue will find their permanent resting-place in the Botanical Museum located at the Owens College, where it will be accessible to Palæo-botanical students in all future time. Hence, such students will have no difficulty in examining for themselves the facts upon which my various hypotheses have been based, as well as in testing the accuracy or otherwise of my figures and descriptions. But I have further availed myself of the opportunity afforded by the publication of this Index to remedy some other defects and omissions in the original memoirs. Thus in some of the earlier publications no provisional names were attached to the type-forms figured. There was also, in some cases, a want of a more condensed definition of those types. In some other instances suggestions were made which my later investigations have failed to sustain. I have also neglected in several cases to indicate what names of the types emanate from myself and what have been adopted from other writers. Most of these defects will be remedied as my present work proceeds. The whole will, I trust, not be without some little additional influence in advancing our knowledge of Palæo-botanical Science.

LIST OF WORKS AND GENERAL INDEX

ON THE ORGANISATION OF THE

FOSSIL PLANTS OF THE COAL MEASURES.

Symbols.	*Parts.*	
A.	I.	Calamites and suggested genus Calamopitus (not subsequently insisted upon). Figs. 16 & 17 do not belong to Calamites but to the subsequently adopted genus Astromyelon. *Phil. Trans.*, 1871.
B.	II.	Lepidodendron selaginoides, Diploxylon (Corda), Ulodendron, Favularia, Sigillaria, Stigmaria, Lepidodendroid Cone (?) ultimately Lepidodendron parvulum. (*Memoir* XVI.) Anabathra. *Phil. Trans.*, 1872.
C.	III.	Lepidodendron brevifolium. (Burntisland form) and its Lepidostrobus. Restoration of Lepidodendron. *Phil. Trans.*, 1872.
D.	IV.	Lyginodendron Oldhamium; Heterangium Grievii. *Phil. Trans.*, 1873.
E.	V.	Asterophyllites with Sphenophylloid axis. Sphenophyllum. Volkmannia (subsequently Bowmanites) Dawsoni, Strobilus of Asterophyllites (subsequently Paracalamostachys Williamsoniana; Weiss) Asterophyllites fruit (subsequently Palæostachya pedunculata. (See Weiss. Steinkohlen-Calamarien). Calamostachys Binneyana, Calamites verticillatus. Root of Asterophyllites (afterwards Amyelon). *Phil. Trans.*, 1874.
F.	VI.	Rachiopteris aspera (afterwards petiole of Lyginodendron Oldhamium) Rachiopteris Oldhamium, Rachiopteris duplex, Rachiopteris Lacattii, Rachiopteris bibractensis, Anachoropteris Decaisnii. *Phil. Trans.*, 1874.
G.	VII.	Myelopteris (Medullosa of Cotta), Psaronius Renaultii, Kaloxylon Hookeri. *Phil. Trans.*, 1876.
H.	VIII.	Rachiopteris corrugata, Fern Sporangia, Gymnospermæ, Dadoxylon, Gymnospermous Seeds, Lagenostoma ovoides, Lagenostoma physoides, Conostoma oblonga, Conostoma ovalis, Conostoma intermedia, Malacotesta oblonga, Trigonocarpon olivæforme, Hexapterospermun Nöggerathi, Cardiocarpon anomalum, Cardiocarpon compressum, Cardiocarpon acutum, Cardiocarpon Butterworthii, Polypterospermum. *Phil. Trans.* 1877.
I.	IX.	Astromyelon, subsequently A. Williamsonis, Calamites, Asterophyllites, Lepidodendron selaginoides, Lepidostrobus, Macrospores, Rachiopteris rotundata, Rachiopteris cylindrica, Cordaites (?) epiderm, Lyginodendron (?) anomalum, Lepidodendroid cortex, Oidospora anomala, Volkmannia (?) parvula. *Phil. Trans.*, 1878.

K. X. Arran Lepidodendron, subsequently L. Wunschianum, Heterosporous Lepidostrobus, Calamostachys Binneyana, Rachiopteris insignis, Tylosis, Rachiopteris robusta, Sporocarpon elegans, Sporocarpon pachyderma, Sporocarpon asteroides, Sporocarpon ornatum, Traquaria, Zygosporites (subsequently shewn to be spores), Dadoxylon, Lagenostoma ovoides, Cardiocarpon anomalum, Calcisphæra (Radiolariæ of Judd). *Phil. Trans.*, 1880.

L. XI. Lepidodendron selaginoides, Lepidodendron Harcourtii. (The plant so named here is now designated L. fuliginosum. See *Proceedings Royal Society*, Vol. XLII., p. 6.) Stigmarian rootlets, Medullary rays of Lepidodendron selaginoides, Calamostachys Binneyana and C. Casheana, Fungi. *Phil. Trans.*, 1881.

M. XII. Astromyelon Williamsonis, Psaronius Renaultii, Zygosporites (in a Sporangium), Calamites, Lepidodendron, Halonia, Sporocarpon ornatum, Salisburia Adiantifolia. *Phil. Trans.*, 1881.

N. XIII. Heterangium Tiliæoides, Kaloxylon Hookeri. *Phil. Trans.*, 1887.

O. XIV. True fructification of Calamites. *Phil. Trans.*, 1888.

P. XV. Rachiopteris Grayii. Rachiopteris Lacattii; Calamostachys Binneyana, Rachiopteris hirsuta, Rhizonium verticillatum, Rhizonium reticulatum, Rhizonium lacunosum.

Q. XVI. Lepidodendron Harcourtii, Lepidodendron mundum, Lepidodendron Spenceri, Lepidodendron parvulum, Rachiopteris inæqualis. *Phil. Trans.*, 1889.

R. XVII. Lyginodendron Oldhamium, Bowmanites (Volkmannia) Dawsoni. Calamites. 1890.

S. XVIII. Bowmanites Dawsoni. Rachiopteris ramosa, possibly R. hirsuta var. ramosa. [*Not yet published.*

T. "On the structure of the woody Zone of an undescribed form of Calamite." *Memoirs of the Manchester Literary and Philosophical Society*, 3rd Series, Vol. IV., Session 1868-9.

V. "On a new form of Calamitean Strobilus." *Memoirs of the Manchester Literary and Philosophical Society*, 3rd Series, Vol. IV., Session 1869-70.

W. "On some Anomalous Oolitic and Palæozoic forms of vegetation." Royal Institution of Great Britain, Weekly Evening Meeting, Feb. 16, 1883.

X. "On the relations of Calamites to Calamodendron," with description of an intermediate form. *Memoirs of the Manchester Literary and Philosophical Society*, 3rd Series, Vol. X., 1886-7.

Y. A Monograph on "the Morphology and Histology of Stigmaria ficoides." *Palæontographical Society*, Volume for 1886.

Z. "On the Structure and Affinities of some Exogenous stems from the Coal measures." *Monthly Microscopical Journal*, Aug. 1, 1869.

SPECIAL INDEX

TO THE DESCRIPTIONS OF

MORPHOLOGICAL AND HISTOLOGICAL STRUCTURES

DEALT WITH IN THE MEMOIRS.

FAMILY CALAMARIÆ. *Endlicher.*

GENUS CALAMITES. Suckow.

Calamites. Arthropitus. Calamodendron. Calamopitus. Calamodendroxylon. Calamodendrophloyos. Calamodendrea. *Auctorum.*

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Cortex.

O.—p. 50, Fig. 10e, C.N. 1570.

PERIPHERAL APPENDAGES.

Nodal Disk.

O.—p. 50-1, Fig. 1h, C.N. 110. Fig. 4e, C.N. 1564. Fig. 5hh, C.N. 1573. Fig. 20h.

Lacunæ of Disk.

O.—p. 50, Fig. 1i, C.N. 110. Fig. 4i, C.N. 1564. Fig. 18i, fig. 20i.

Marginal Disk Rays.

O.—p. 50, Fig. 3k', C.N. 1567. Fig. 10k', C.N. 1550. Fig. 13k, C.N. 1579. Fig. 14k, C.N. 1563. Fig. 20k.

Sporangiophores.

O.—p. 52, Fig. 1ll', C.N. 110. Fig. 2l, C.N. 1583. Fig. 3l, C.N. 1567. Fig. 10ll' C.N. 1570. Fig. 12, Fig. 13ll', C.N. 1579. Fig. 20l.

Sporangia.

O.—p. 52-3, Fig. 2m, C.N. 1583. Fig. 3m, C.N. 1567. Fig. 13mm', C.N. 1579. Fig. 14mm', C.N. 1563.

Spores.

O.—Fig. 150.

INORGANIC CASTS OF THE MEDULLARY CAVITY OF CALAMITES.

A.—p. 490, Fig. 23a, C.N. 42. Fig. 24a, C.N. 39. p. 492, 494, 496-98, Figs. 27, 28, 29, 30, 31, 32, 33, 34, 36.

T.—p. 164, Fig. 13, C.N. 53.

R.—p. 102, Fig. 22, C.N.

X.—Fig. 1a, C.N. 1933.

Impressions on Shale.

I.—p. 329, Fig. 30.

Casts of young branches.

A.—p. 493.

R.—p. 101, Fig. 21, C.N. 1934.

Carbonaceous investments of Casts.

A.—p. 494.

Longitudinal grooves and ridges of Casts.

A.—p. 489, 493, Fig. 26, p. 495, Figs. 29-30.

R.—p. 101-2, Figs. 20, C.N. 114, 21, C.N. 1934. Fig. 22, C.N. 1933. See also 1944.

Transverse Constrictions of Casts.

A.—p. 480. Fig. 10, C.N. 11. Fig. 24, C.N. 39.

I.—p. 324, Fig. 15n, C.N. 80.

T.—p. 162, Fig. 10.

X.—Fig. 1a, Fig. 3f.

RELATIONS TO CALAMODENDRON.

A.—501-2, 506.

I.—p. 322, 331.

T.—p. 174.

See also Memoir K.

EQUISETACEOUS RELATIONS.

A.—p. 502-6, Figs. 41, 42, 43, p. 506.

I.—p. 331.

O.—p. 47.

CALAMITINA. *Weiss.*

CALAMITES. *Auctorum.*

CALAMITINA VERTICILLATA.

CALAMITES VERTICILLATUS. *Lindley & Hutton.*

E.—p. 66-67, Fig. 45. Owens College Museum.

PALÆOSTACHYA. *Weiss.*
ASTEROPHYLLITES. *Will.* VOLKMANNIA. *Sternberg.*
CALAMITES. *Brongniart and Lindley and Hutton.*
PALÆOSTACHYA PEDUNCULATA. *Will.*

See *Weiss.* "Abhandlungen Zur Geologischen Specialkarte von Preussen und den Thuringischen Staaten." Band V., Heft. 2, p. 182.

E.—p. 57-58, Fig. 32, C.N. 1060.

PARACALAMOSTACHYS. *Weiss.*
ASTEROPHYLLITES. *Will.*
PARACALAMOSTACHYS WILLIAMSONIANA.

Weiss, ut supra p. 193.

Stem.

E.—p. 57, Fig. 44, C.N. 1058.

Strobilus.

E.—p. 57, Fig. 31, see C.N. 1057.

ASTEROPHYLLITES (in part). *Brong.*
ASTEROPHYLLITES SPHENOPHYLLOIDES. *Will.*

AXIS.

Vascular Bundle. Primary. Transverse.

E.—p. 42, Fig. 1e, C.N. 871. p. 42, Fig. 2c.

Secondary Exogenous Zones. Transverse.

E.—p. 43, Fig. 2d, C.N. 872. Fig. 3d, Fig. 4, C.N. 871. p. 45, Fig. 9, C.N. 891. Fig. 10, p. 46, Fig. 11, C.N. 900. Fig. 12, C.N. 900.

Tracheids.

E.—p. 44, Fig. 6; see C.N. 893.

Medullary Rays.

E.—p. 46-7, Fig. 13, C.N. 891.

CORTEX.

Transverse inner.

p. 43, Fig. 4, C.N. 871. p. 45, Fig. 9, C.N. 891. p. 46, Fig. 10; see C.N. 894. Fig. 16 g-h.

Outer.

E.—p. 4b, Fig. 1, C.N. 871. p. 43, Fig. 2, C.N. 872. Fig. 4, C.N. 871. Fig. 16k″, C.N. 874.

CORTEX. LONGITUDINAL.

Inner.

E.—p. 44, Fig. 5g-h, C.N. 871, Fig. 7.

Outer.

E.—p. 44, Fig. 5k, C.N. 871, p. 45, Fig. 8.

NODAL CORTICAL DISKS.

Transverse.

E.—p. 48. Fig. 16k", C.N. 874.

I.—p. 332, Fig. 32, C.N. 908.

Longitudinal.

E.—p. 47, Fig. 5. C.N. 871. Fig. 15, C.N. 875. See also C.N. 904.

LEAVES.

Longitudinal.

E.—p. 47, Fig. 14m", Fig. 15m, C.N. 875. See also C.N. 904.

Transverse.

E.—p. 49, Fig. 14m', Fig. 17.

I.—p. 333, Fig. 32mm', C.N. 908.

Verticillate arrangement.

E.—p. 47.

I.—p. 333, Fig. 32mm' C.N. 908.

ASTEROPHYLLITES INSIGNIS. *Will.*

BURNTISLAND (PETTICUR) PLANT.

YOUNG TWIG.

Primary Xylem.

E.—p. 49, Figs. 18, C.N. 909. Fig. 19, C.N. 917.

OLDER BRANCHES.

Secondary Xylem.

E.—p. 49, Fig. 20. See C.N. 919. p. 50, Fig. 21. C.N. 913.

Tracheids.—p. 51, Figs. 23, 24, 25, for transition from barred to reticulate Tracheids see C.N. 922 and 923.

Medullary rays.—p. 51, Fig. 22, C.N. 892.

CORTEX.

E.—p. 49, Fig. 19, C.N. 917. Fig. 21h, 50, C.N. 913.

No leaves or Nodal Developments of this plant have yet been discovered.

Divergent Tracheides; to a branch?

E.—p. 52, Fig. 27x, C.N. 926.

Roots of Asterophyllites?

See *Amyelon* E.—p. 67 et seq. p. 71.

*Relations to Sphenophyllum.**

E.—p. 73-75.

I.—p. 332-5.

R.—p. 97-98.

* The Lycopodiaceous affinities of Asterphyllites and Sphenophyllum dwelt upon by me in Memoir E must now be withdrawn, as not in accord with our more recent knowledge.

SPHENOPHYLLUM. *Brongniart.*

E.—p. 42, Fig. 26, Owens College Museum.

CALAMOSTACHYS BINNEYANA.

CALAMOSTACHYS. *Schimper.*

CALAMOSTACHYS BINNEYANA. *Schimper.*

CALAMODENDRON COMMUNE. *Binney.*

VOLKMANNIA BINNEYI. *Carruthers.*

VASCULO-CELLULAR AXIS.*

Medulla.†

C.N. 1001. C.N. 1016.

K.—p. 503, Fig. 13a, C.N. 1039. p. 503, Fig. 15a, C.N. 1043.

P.—p. 160, Fig. 7a, C.N. 1004. Fig. 8a, C.N. 1008.

Tracheids.—Longitudinal Section.

K.—Fig. 13a.

Transverse Section.

E.—p. 61, Fig. 38, C.N. 989. p. 72.

P.—p. 160, Fig. 7b, b′, C.N. 1004. Fig. 8a, C.N. 1000.

Exogenous growth of ?

E.—p. 72, Fig. 38.

K.—p. 504-5, Fig. 16, C.N. 1016.

ALTERNATION OF NODES.

Sterile.

E.—p. 59, Fig. 33, C.N. 1045*. Fig. 34, C.N. 994.

K.—p. 503, Fig. 13e.

Fertile.

E.—p. 60, Fig. 36, C.N. 991.

K.—p. 503, Fig. 13d, C.N. 1039.

* Vascula-medullary axis. There has been much difficulty in defining the structure of this axis, which varies much in different specimens. In Memoir E, Figs. 37-38, we have the axis of the specimen C.N. 989. Its centre is probably cellular, not vascular as described in the Memoir; but it is surrounded by a zone of radially disposed Tracheids, of which the orientation is specially related to the three points d, d, d, as described in the Memoir, and indicating some relationship to the triquetrous vascular axis of the Asterophyllites, described in the same Memoir. Similar conditions are seen in other specimens in my cabinet—markedly so in C.N. 1014 and 1016, in which the central medulla is distinctly cellular, but in which the peripheral vessels are as distinctly arranged in three externally convex groups. An identical arrangement appears in the Calamostachys Ludwigi figured by Herr Weiss in his "Steinkohlen Calamarien II." Taf. 24. In another transverse section (C.N. 1094) these tracheids are clustered at four angles of a somewhat quadrate section. Other minor features suggest that more than one species may be comprehended under the name of Calamostachys Binneyana.

† When writing Memoirs E and K, I had failed to discover this organ. The central axis was erroneously described as wholly vascular, the elongated medullary cells being mistaken for Tracheids.

Internode.

E.—p. 61, Fig. 37, C.N. 989.

K.—Fig. 13, spaces between c and d, C.N. 1039.

CORTEX.

E.—p. 60, Fig. 36k, C.N. 991. p. 61, Fig. 37k, C.N. 989.

K.—p. 503, Fig. 13b, C.N. 1039. Fig. 14b, C.N. 1029.

P.—p. 160, Fig. 8k, C.N, 1000.

DISKS.

Sterile.

E.—p. 59, Fig. 33k″, C.N. 1045.* p. 60, Fig. 34k, C.N. 994. p. 59-60, Fig. 35.

K.—p. 503, Fig. 13c, C.N. 1039. Fig. 14c, C.N. 1029.

L.—p. 299, Fig. 27t.

Disc-rays.

E.—p. 59, Fig. 33, C.N. 1045*. p. 60, Fig. 34tt″, C.N. 994. p. 59-60, Fig. 35t,t′,t″, p. 60, Fig. 36t,t′, C.N. 991. p. 61, Fig. 37t, C.N. 989.

K.—p. 503, Fig. 13, C.N. 1039. Fig. 14c-f, g, C.N. 1029.

L.—p. 299, Fig. 27t′.

P.—p. 160, Fig. 8g, g′, C.N. 1000.

Fertile Discs (Lateral extension small).

E.—p. 60, Fig. 36k, C.N. 991.

K.—p. 503, Fig. 15d, C.N. 1043.

P.—p. 160, Fig. 8k, C.N. 1000.

ORGANS OF REPRODUCTION.

Sporangiophores.

E.—p. 60-61, Fig. 36v, C.N. 991. Fig. 37v, C.N. 989.

L.—p. 298, Fig. 23v, C.N. 1017.

P.—p. 160, Fig. 8v, v′, v″, C.N. 1000.

Attachment of Sporangia to Sporangiophores.

L.—p. 298, Fig 23, v″, v‴, C.N. 1017.

Sporangia.

E.—p. 60-61, Fig. 36u, C.N. 991. Fig. 37, C.N. 989.

K.—p. 505, Fig. 18, C.N. 1011. See also C.N. 1008.

P.—p. 160, Fig. 8u, C.N. 1000.

Sporangium wall.

E.—p. 62, Figs. 39, 40, 41, 42. See C.N. 1029-1031.

Spores.

E.—p, 62-63, Fig. 43.

K.—P. 505, Fig. 17, C.N. 1018. See also 1589.

Supposed Lycopodiaceous Affinities.

L.—p. 299. These suggestions have not been sustained by my later researches.

CALAMOSTACHYS CASHEANA. *Will.*

(Report of British Association for the Advancement of Science, 1886.)

Cortex.

L.—p. 299, Fig. 24k, C.N. 1024.

Sterile Disk.

L.—p. 299, Fig. 24t, C.N. 1024.

Disk-rays.

L.—p. 299, Fig. 24t', C.N. 1024.

Fertile Disk.

L.—p. 299, Fig. 24v', C.N. 1024.

Sporangiophores.

L.—p. 299, Fig. 24v, C.N. 1024.

Micro-sporangia.

L.—p. 299, Fig. 24u, C.N. 1024.

Macro-sporangia.

L.—p. 299, Fig. 24u', C.N. 1024.

Microspore.

L.—p. 299, Fig. 25.

Macrospore.

L.—p. 299, Fig. 26.

Additional examples of *C. Casheana*, C.N. 1025, 1587 and 1588.

POTHOCITES. *Paterson.*

POTHOCITES GRANTONI. *Paterson.*

W.—p. 9-10, Fig. 9, C.N. 1056.

Bowmanites Dawsoni, Will. belongs to the group of the Calamariæ, but since a memoir recording my more recent researches respecting it is in preparation, the Index relating to it will appear in Part II.

The History and present position of the Theory of Glacier motion. By H. H. Howorth, M.P., F.S.A.

(Received December 12th, 1890.)

It is not usual to read papers before this Society which contain neither new facts nor new inferences. I nevertheless hope that the following memoir, which embodies the results of considerable labour, may be acceptable on grounds which I will state.

The theory of Glacier motion has involved a long and difficult polemic, in which nearly all the distinguished physicists of the last century have taken part, and in the course of which many hypotheses have been forthcoming and been in turn discarded. In this it shares the fate of many other theories. Where it differs from the rest is in that, whereas at one time opinion gradually converged upon one explanation, namely, that of Forbes, as alone meeting the facts, that explanation was in turn sharply challenged on empirical and *a priori* grounds, and for many years it had to give place to other theories which seemed more plausible. Quite recently again, more accurate and careful experiments have shown that Forbes was substantially, if not entirely, right. This fact has scarcely yet permeated scientific opinion, and is certainly hardly yet appreciated, and as it is of the first moment in settling questions of far-reaching importance in general physics, and especially in theoretical geology, and as it forms the basis of an attack which I have long been preparing upon what I venture to style the Glacial Nightmare of modern geology, I trust I may claim your considerate attention for what I have to say. I have tried to make the paper as complete a monograph as possible,

and have thought it best and most honest to state each man's views in his own words. The general argument and arrangement are of course my own.

As we rise in the atmosphere the cold increases and we speedily reach a height when the temperature is always below the freezing point of water all the year round. It is clear that above this line no rain falls, but only snow, and further that this snow when it falls remains in the condition of snow, and does not melt, except a thin superficial layer due to the influence of the direct rays of the sun, which is very slight. Above this line, then, not only does the snow remain as snow, but also as dry snow, and in a loose, powdery condition, on which no ordinary pressure will alter its structure or convert it into ice. This is the case on the higher Himalayahs and the Andes. Below this line the temperature is at some seasons of the year above the freezing point of water, and the snow is consequently more or less melted annually, and is also in a more or less damp and moist condition. This line, therefore, marks an important frontier in the meteorological features of the high-lands.

Let us now turn to another such frontier, namely: the line separating the zone where all the snow which annually falls is melted away and that in which only a portion of it is melted: this is known as the snow line. This line varies in height according to the latitude. At the Equator it is about 16,000 feet above the level of the sea, and it sinks to about the sea level near the Poles. Above the snow line and below the line where the temperature is always under the freezing point of water, a certain portion of the snow which falls annually is melted by the summer heat, while another portion gradually augments in thickness from the snow line upwards. Tyndall describes one portion of the process in his usual graphic manner: "The sun first raises the superficial snow to 32° and then melts it. The

water thus formed percolates through the cold mass below and expels the air entangled in the snow, the liquid trickles down and gets frozen on to the granules which it meets with colder than itself, augments them in size, and cements them together." By this process, assisted by the consolidating influence of pressure, there is formed a mass of white, opaque, frozen and consolidated, half snow half ice, the whiteness and opacity being due to the myriad air bubbles which it encloses.

This white opaque mass is what the French call *névé* and the Germans *Firn*. Its superficial layers are more snowy and white, and consist of nearly pure snow, while the deeper ones have more colour and consistence, and break on the larger scale into vast fragments, which are called seracs. The upper part of the *névé* is stratified, each stratum representing a considerable distinct snow-fall, but as we pass down into the more condensed and more solid ice, these signs of stratification disappear, and it assumes a homogeneous and more or less granular consistency.

"The granulated structure of the *névé*," says Forbes, "is accompanied with the dull white of snow passing into a greenish tinge, but rarely, if ever, exhibiting the transparency and hue of the proper glacier. The crevasses in the *névé* are wider and more irregular than in the proper glacier; the colour transmitted by them is green; the substance of the *névé* is much more easily fractured than ice, and is also more readily thawed and water worn, and it often contains huge caverns, in which are pendent icicles ten and twenty feet in length." Gradually the *névé* passes, as we descend into true glacier-ice, blue in colour, and close and transparent in texture.

It is important to note, and to remember, that glacier ice is, in internal structure, very different to ordinary ice made by freezing water in a pond or laboratory. It is formed out of granulated *névé*, and it never loses the

characteristic of granulation. As Messrs. McConnell and Kidd say in their recent paper, "Glacier ice is a sort of conglomerate formed of glacier grains *(Gletscherkörner)*, differing, however, from a conglomerate proper in that there is no matrix, the grains fitting each other perfectly. In the winter, at any rate, the ice on the sides of the glacier caves looks quite homogeneous. But, when a piece is broken off and exposed to the sun's rays, the different grains become visible to the naked eye, being separated probably by thin films of water. Though the optical structure of each grain is found under the polariscope to be perfectly uniform, the bounding surfaces are utterly irregular, and are generally curved. The optic axes too of neighbouring grains seem arranged quite at random" (*Proceedings, Royal Society*, XLIV. 333—334).

M. Forel, who has devoted much labour to the elucidation of the internal structure of glaciers, thus defines this curious feature of glacier ice: "The mass of the glacier is formed of an agglomeration of crystals pressed against each other, and so interlocked and intertwisted that it is difficult to separate them, and forming a piece of compact masonry of ice crystals. The crystals are irregular in shape, some with their parts curved, and their axes apparently lie in all directions. These glacier crystals it has been shewn (*vide infra*) grow from the size of a small lentil near the *névé* to that of a hen's egg at the base of the glacier." M. Forel succeeded in imitating glacier ice by alternately allowing snow to freeze and pouring over it water above 0° centigrade in temperature. In this way, ice of the granular texture of glacier ice was produced, and it apparently follows that a glacier is formed by the periodical melting of its surface by the sun, rain, etc., and its subsequent freezing, a process assisted by the presence of the two containing walls of the valley in which it lies. It is most important in this discussion to remember what most of those who have treated of glacier

motion have overlooked, namely, that this granular structure of glacier ice separates it in a very important respect from other ice.

A glacier, then, consists of a solid mass of frozen water, the upper part of loose snow, the middle of semi-consolidated ice, and the lower of ice, properly so-called, which mass is either embowelled in a single mountain valley, or formed of several converging portions, filling several radiating subsidiary valleys, and uniting in one mass in the main depression.

The fact that a glacier is not stationary, but moves in its bed, must have been known at a very early date to the mountaineers of Switzerland. They were witnesses of the gradual progression of its lower part, called the ice foot, which in many cases has overwhelmed meadows and fields and even houses. They must also have noticed the gradual movement of the great masses of stone on the glacier's back, which could be seen year after year to alter their position relatively to the sides. This homely evidence must have made it plain in very early times to the Swiss shepherds and hunters, that glaciers are not reservoirs of stationary ice, but are rather frozen streams in motion. Facts of a more dramatic kind must also have occurred similar to those named by more recent travellers. Thus:—

Toussaint de Charpentier tells us how he was assured by Jacques Balmat, a native of Chamounix, when he was travelling there in 1818, that once in the summer months the Savoyard peasants went with their sheep to graze on a kind of oasis on the Mer de Glace known as "le Jardin," when one of these animals fell into a crevasse and was killed. Some years afterwards the animal came to the surface *some distance down the valley*, and the flesh had been preserved quite fresh (*Naturwissenschaftlicher Anzeiger der All. Schweiz. Gesell. fur die Ges. Naturwiss.* for 1821, page 78).

In 1832 Forbes discovered, near the Moulins, portions of

a ladder which De Saussure had lost on the Aiguille de la Noire, in the year 1788. The distance it had travelled in the 44 years was about 16,500 feet, giving an average of 375 feet per annum as the mean rate of progression (*Travels*, 87).

On September 25th, 1842, the same traveller lost a hammer, which fell into the great Moulin, opposite the ice cascade, du Taléfre. This hammer was recovered on June 22nd, 1858, "not far below the Tacul" (*Forbes's Life and Letters*, 297). On the 29th of July, 1836, the guide Michel Dévouasson lost a knapsack on the Glacier du Taléfre, in a crevasse into which he had fallen. Fragments of this knapsack were found on the Glacier du Lechaud on the 24th of July, 1846, at a distance of 4,300 feet from where it had been lost, which showed an annual progression of 430 feet ("Thirteenth Letter on Glaciers," *Ed. Phil. Journ.*, 1847).

While facts like these must have made the motion of glaciers well known to the Swiss peasants from early times, it was apparently first published to the scientific world by Simmler in his work "De Alpibus," published in the middle of the sixteenth century.

When it was established that glaciers actually move, men began to try and find an adequate explanation of their movement. The various theories which have been suggested all appeal to one of two forces, namely, heat or gravity. We will examine them in turn, and in doing so shall find it convenient not to follow a chronological order, but to first examine the various theories which more or less exclude gravity as a factor in glacier motion and which appeal to the action of heat in various ways.

In his so-called "Itinera Helvetiæ Alpinas Regiones," 1723 (pp. 287—8), J. J. Scheuchzer, referring to the motion of glaciers, says: "The cause of this motion is not owing to any miracle, as those ignorant of physics suppose, but is

to be ascribed to natural causes. The water flowing from the sides of the mountain on to the glacier enters its fissures and interstices, freezes again, and as it needs more space when thus frozen, as experiments have shown, it causes the glacier to thrust forward, and to carry with it sand and stones, some of them of great size," etc. He goes on to say that his opinion in the matter had been confirmed by observations made by two of his friends.

The theory thus hinted at was revived by Toussaint de Charpentier and Canon Biselx in 1819, and was published in "The Transactions of the Swiss Natural History Society" for 1821, p. 77, where it is stated that rainwater as well as water from the melted snow finds its ways into the cracks and cavities of the ice-mass. The water which thus percolates freezes again, swells out, and causes the ice to split and to move. The theory was worked out in detail by T. de Charpentier's more famous brother, J. de Charpentier, and by Agassiz, and is known as the Dilatation theory.

Agassiz, its best known advocate, states his case thus: "Ce mouvement paraît plutôt être dû à la dilatation de la glace résultant de la congélation de l'eau qui s'infiltre continuellement dans les fissures capillaires que présente la glace, dans toute son épaisseur, et surtout à la partie la plus voisine de la surface où elle est moins compacte. Cette eau, dont la température est constamment voisine du point de congélation, se transforme en glace au moindre abaissement de température, et tend à dilater le glacier dans tous les sens. Cependant, comme il est contenu des deux côtés par les flancs de la vallée, et en amont par le poids des masses supérieures, toute l'action de la dilatation, aidée d'ailleurs de celle de la gravitation, se porte dans le sens de la pente, vers le seul côté qui offre une libre issue" ("Notice sur les glaciers," published with Desor's *Journal d'une course aux glaciers, etc., 1840*).

The position is thus stated with his usual clearness and fairness by Principal Forbes: "The snow is penetrated by water, and gradually consolidated. It remains, however, even in the state of ice, always permeable to water by means of innumerable fissures which traverse the mass; these are filled with fluid water during the heat of the day, which the cold of the night freezes in these fissures, producing, by the expansion which freezing water undergoes in that process an immense force, by which the glacier tends to move itself in the direction of least resistance—in other words, down the valley. This action is repeated every night during summer, in winter the glacier being assumed to be perfectly stationary" (*Forbes's Travels*, 34).

When J. de Charpentier read a paper in 1838 before the Helvetic Society of Natural Science on the dilatation theory, M. Merian replied that if the theory were true, glaciers ought to augment in height alone, since the direction of least resistance would be vertically. In this he was supported by M. Studer, who quoted what takes place when anhydrite is converted into gypsum, or lime into dolomite, when the mass swells upwards. This view was also pressed by Hopkins. But the notion that a glacier swells upwards is quite contrary to the careful observations of Forbes. Studer also pointed out that the nocturnal cold only freezes a very superficial layer of the glacier, and that in order that the water should freeze in the crevasses or cracks the temperature must be below zero of Réaumur, which is lower than we know the temperature to be at the base of glaciers (*Mémoires*, *op. cit.*, pages 113—114).

Hopkins argued that while it is true that water freely percolates through certain kinds of glacier ice, it cannot be proved that it freezes in the interstices. "The temperature of the upper portion of a glacier," he says, "where the percolation has been observed, is very little below that of freezing, and does not appear to be sufficiently low to convert water into ice while moving with the freedom with

which it descends through the glacier. Wherever congelation does take place, the capillary pores must be filled up, and where it does not, the percolating water must proceed till it meets with the larger fissures, through which it will descend freely to the bottom of the glacier."

Forbes's refutation of the theory of dilatation was twofold. He replied to it on *a priori* and on experimental grounds. Thus he says, "The dilatation theory is founded on a mistake as to a physical fact. . . . . The maximum temperature which a glacier can have, observes M. de Charpentier (*Essai*, pp. 9 and 104), is 0° centigrade or 32 Fahr., and the water in its fissures is kept liquid only *by the small quantity of heat* which reaches it from the surface water and the surrounding air. Take away this sole cause of heat, *i.e.*, let the surface be frozen and the water in the ice must congeal. Now this is a pure fallacy; for the fact of the latent heat of water is entirely overlooked. The latent heat of water expresses the fact that where that fluid is reduced to 32° it does not immediately solidify, but that the abstraction, not of a small quantity but a very large quantity indeed, is necessary to convert the water at 32° into ice at 32°. Not a great deal less heat must be abstracted than the difference between the heat of boiling water and that at common temperatures. The fallacy, then, consists in this: Admitting all the premises, the ice at 32° (it is allowed that in summer during the period of infiltration it cannot be lower) is traversed by fissures extending to a great depth (for otherwise the dilatation would be only superficial) filled with surface water at 32°. Night approaches, and the surface freezes, and water ceases to be conveyed to the interior. Then, says the theorist, the water already in the crevices and fissures of the ice, and in contact with ice, instantly freezes. Not at all; for where is it to deposit the heat of fluidity, without which it cannot under any circumstances assume the solid form? The ice

surrounding it cannot take it; for being already at 32°, it would melt it. It can, therefore, only be slowly conveyed away through the ice to the surface, on the supposition that the cold is sufficiently intense and prolonged to reduce the upper part of the ice considerably below 32°. The progress of cold and congelation in a glacier will therefore be, in general, similar to that in the earth, which, it is well known, can be frozen to the depth of but a few inches in one night, however intense the cold. Such a degree and quantity of freezing as can be attributed to the cold of a summer's night must therefore be absolutely inefficient on the mass of the glacier" (*Forbes's Travels*, 36—37.)

This reasoning seems unanswerable. Forbes elsewhere refers to an experimental proof. He says, "The most direct observation shews that the nocturnal congelation which is so visible at the surface, drying up the streamlets of water, and glazing the ice with a slippery crust, extends, but to the most trifling depth, into the mass of the glacier. This is so evident upon consideration that, when fairly placed before him, M. de Charpentier has been obliged to abandon the idea that the diurnal variation of temperature produces any effect. In truth there is positive evidence that no internal congelation takes place during the summer season, when the motion is most rapid, and when, therefore, the cause of motion must be most energetic" (*id.* 358). He then goes on to describe how on one occasion he traversed the Mer de Glace up to the higher part of the Glacier de Lechaud, while it was covered with snow to a depth of six inches at Montanvert, and three times as much in the higher part. It was snowing at the time, and for a week the glacier had been in the same state nearly, the thermometer having fallen, meanwhile, to 20° Fahr. . . . All the superficial rills were frozen over, there were no cascades in the "Moulins," all was as still as it could be in mid-winter; yet even on the Glacier de Lechaud my wooden poles sunk to

a depth of less than a foot in the ice, were quite wet, literally standing in water, and consequently unfrozen to the walls, and in the hollows beneath the stones of the moraines, by breaking the crust of ice, pools of unfrozen water might be found almost on the surface" (*Theory of Glaciers*, 32—33, *Travels*, 359—360). Forbes goes on to say that "if the dilatation theory were correct, a sudden frost succeeding wet weather must inevitably cause the glacier to advance far more rapidly than in summer, or indeed at any other season, for there could never possibly be more water to be frozen or could cold ever act with more energy than at the time in question, but the contrary was found to be the case, and directly the severe weather passed and the little congelation which had taken place thawed, and the snow was reduced to water, then the glacier, saturated in all its pores, resumed its march nearly as in the height of summer." Thirdly, he urges that the well-established motion of glaciers in winter is directly inconsistent with the views of those who urge dilatation as the result of alternate congelation and thaw, and as the motive force which impels them, since, when the glacier is completely frozen, this cannot occur. The fact that the motion of the glacier during the day and night is sensibly uniform points the same way. If the theory were true, again, the motion of the glacier ought to vanish near its origin and increase continually towards its lower extremity. "I have found," he says, "the motion of the higher part of the Mer de Glace to differ very little from that several leagues further down; while in the middle, owing to the expansion of the glacier in breadth, its march was slower than in either of the other parts" (*Theory of Glaciers*, 33—34, *Travels*, 363—4).

In addition to these arguments Heim urged that, since water only expands to the extent of one-ninth of its volume in freezing, the total motion which ensues from the

freezing of the water in the capillaries of a glacier is very slight, and, further, that as the glacier gets consolidated, these capillaries gradually disappear, and with their disappearance disappears also the *primum mobile* postulated by the dilatationists. He also urged that if the dilatation theory were true, the maximum of motion in a glacier should be greatest in the evening, when the water in the capillaries freezes, or in the morning when it should melt, which is not found to be the case (Heim, *Gletscherkunde*, 294—5, see also Mousson *Gletscher der Jetztzeit*, 155, etc.).

Mr. Bonney, in regard to this theory, says it fails to explain the motion of glaciers in the coldest winters, and the fact that it is not liable to any marked change when there is a sudden alteration in the temperature of the surrounding air. Nor have its advocates proved the existence of the fine capillaries necessary for it to work upon. On the contrary, Huxley and Tyndall shewed that, except at the surface, a glacier is formed of compact ice impenetrable to coloured liquids.

In addition to these various converging and irresistible difficulties, the dilatation theory does not account for the fact that the motion of glaciers has been shewn to exist in the deep blue ice, where there are no fissures, as well as in the superficial ice. Nor for the fact of the continuously differential motion which has also been shewn to pervade all parts of the glacier. It has long been discarded, and was, I believe, discarded by its greatest champion, Agassiz, before he died.

We will now turn to a development of the dilatation theory, which still has some supporters.

As early as 1822 Hugi had noticed the granular structure of glacier ice to which I have referred, and he urged that if we examine the most compact ice of glaciers when it is melting, this granular structure is displayed. (Hugi, *Der Gletcher*, etc., 8, etc.) He further showed that the size of these

glacier crystals increases progressively from the higher part of the glacier to the lower, and that they are in a state of gradual growth. This observation has been amply confirmed (*Id.* 9, etc.), and notably by Bertin and Grad, who employed the polariscope for the purpose. It must be confessed that the process here described presents some very great puzzles and difficulties for the physicist. How the crystals in a compact mass of ice can grow from the size of small nuts to that of a hen's egg, granting even that the growth takes centuries to develope, is a very great puzzle. They clearly can only grow by in some way attracting fresh water to themselves. Hugi supposed that the water which they enlist comes to them in the form of atmospheric vapour, since his experiments had shewn him that the mass of the glacier was not permeable to liquids, a result in which, as we have seen, he was confirmed by Huxley, and he further went on to urge that it was by this growth that the movement of ice in glaciers is in fact produced.

Grad contended that in his own experiments infiltration of water was shewn to be possible (*Comptes-Rendus*, CXIX. 957), and went on to urge that the cause of glacier movement is the infiltration of water into the capillary fissures and its subsequent freezing on the crystals of ice forming the glacier, which are consequently enlarged and made to assume a constant instead of a heterogeneous direction like those of frozen water. The expansion thus caused developes a general movement of the ice in the direction of least resistance, in other words, he says, "la masse même du glacier s'accroît par intersusception, et c'est ce developpement ou cette croissance qui provoque le mouvement" (*Comptes-Rendus* for 1867, Vol. LXIV. 46—47).

Practically the same views were pressed at greater length and with greater elaborateness by Forel, who, in 1882, published a paper in the *Archives des Sciences physiques et naturelles* of Geneva entitled, "Le Grain du Glacier." He

contended that while the glacier crystals are very compact, they are bounded by capillary fissures in which water circulates freely when the glacier *is at melting temperature*, and he explained that Hugi's results were consistent with this view. They were made with ice at lower temperatures. He urged with Grad that the crystals increase from the water which melts in summer and permeates the glacier, and freezes in winter. He distinguished between his own view and that of Charpentier. The latter, he urged, attributed the movement of the glacier to the dilatation caused by the passage of water into ice in the capillary fissures. According to this alternative theory, the continuous increase in bulk of the glacier is due to the continuous growth of the small crystals which compose it, the growth of the various parts combining in a growth and therefore in a movement of the whole.

Hagenbach, in order to account for the growth of the crystals, instead of postulating an infiltration, urged that the crystals absorb each other, and thus grow at each other's expense. In regard to Hagenbach's view, Forel urged that, if true, we ought to find in the "glacier grains" a marked inequality of size, some growing and some diminishing in size, whereas the mass of the glacier is formed of grains of virtually the same size in the same district (*Le Grain du Glacier*, 334).

M. Hagenbach to some extent concedes this objection as a valid one, but suggests that the infrequency of the occurrence of small crystals may only mark the surface layers.

In regard to Forel's view, it involves equal, if not greater, difficulties. In order that crystals of ice may increase in size in the interior of a glacier, its temperature must fall considerably below zero. Forel himself has calculated that if there is to be an annual increase of 0·043 in volume, or 0·014 in length, in a glacier crystal, its interior must sink to -7, a conclusion which is certainly not borne out by the experience we have of the temperature of

glaciers. Again, so far as we know, the crystals forming a glacier are in contact with each other when its temperature is below zero. Capillary fissures only develop between the crystals when the ice begins to melt. These fissures do not apparently exist at all, nor is ice permeable to liquids when below the freezing point, and at a temperature therefore where the growth of the crystals can alone take place, and if we limit the actual growth of the glacier crystals to the winter when the temperature may perhaps be sufficiently low, we cannot appeal to that growth to explain the motion of glaciers, which is greatest in summer.

If we are to attribute the continuous motion of the glacier to this growth of its crystalline components, we must also remember how very slight the motion would be. The water which permeates the capillaries merely fills spaces already in existence, and cannot, therefore, by itself cause any thrust, while in freezing its bulk is only increased by one-ninth of itself; nor can we well see how, when the fissures and capillaries are filled by the infiltration of water in the spring, they can re-open again. No force is available for the purpose. It is not enough to appeal to the water and to the effect of freezing in dilating it—we must also find some force by which the separate crystals of ice shall each year be pulled asunder so as to again cause voids (*id.*, 364). Heim, in criticising the theory to which in a measure he was favourably inclined, urged first on broad grounds that if, as Forel argued, the growth of the glacier was due to the freezing in winter of the water which permeates it in summer, it is hard to see why in Greenland, where the summers are so short and the winters so long, the ice should nevertheless move much faster than that of the Alpine glaciers (*Heim*, 299).

Again, according to Forel, the external cold must first freeze the water in the superficial capillaries, and gradually freeze up those in the lower depths of the glacier. If this

were so, then we ought to find that in the early winter the surface layers move faster than the bottom ones, whereas later on, when the surface water has been some time sealed up and the frost operates deeper and deeper, the motion of the deeper layers ought to be greater than that of the surface ones, which seems contrary to experience.

Again, if the glacier motion is due to a general swelling of its bulk, due to the enlargement of its component grains, how is it that it does not swell upwards in the direction of least tension, as well as downwards in the direction of the most compact ice. Its behaviour ought assuredly to be that of quicklime, etc., when charged with water, which swells and pushes out in the direction of least resistance.

Again, if the motion of the glacier is due to growth of its grains, how are we to account for its moving more quickly in the centre than at the sides? The walls of the glacier no doubt act as a drag on the movement of the glacier by means of friction, but that they exercise a crushing influence on the ice near the sides so as to prevent the creation of fissures or the infiltration of water there more than in the centre, seems an assumption at issue with the evidence.

Again, as Heim says, if the size of the glacier grains is a function of the number and rate of the cooling and melting, and also of the time during which the process has continued, the grains near the sides, which move much more slowly than those in the middle, ought to be ten, or twenty, or thirty times larger, which they are not.

Heim again makes an elaborate calculation to shew that if the movement of the glacier is merely the sum of the movements caused by the growth of the crystals, then the observed rate of melting of a glacier would not compensate for the growth, but would be very much too small, so that we ought to find glaciers continuously and rapidly growing in length and size. He concludes, in fact, that the swelling

of the glacier caused by the growth of the grains must be very slight, if any.

For these reasons and for the further reason that it seems impossible to correlate the differential motion of glaciers, as observed by Forbes and others, with any process of mere general swelling of its bulk, it seems to me that we cannot assign to this cause any but a slight influence in the movement of glaciers.

Let us now turn to another theory which involves dilatation and contraction in another form, namely, that of Mr. Moseley. He had noticed that the lead upon the roof of a church at Bristol gradually descended owing to alternate variations of temperature, and arguing from this, he urged that a glacier's motion was best explained by the alternate expansion and contraction of the ice which forms it, due to variations of temperature, which motion should take place in the direction where it is easiest, namely, down the valley; where expansion would be assisted by gravity, while contraction would be resisted by the same force: thus expansion would gain somewhat upon contraction in every alternation of temperature, and the general centre of gravity of the mass would move down somewhat. Mr. Moseley defended this theory in several papers.

In criticizing it, we must in the first place remember that ice cannot expand with heat when above the freezing point, and, if so, as Mr. Croll pertinently says, how are we to account at all for the motion of glaciers in summer on this theory. When the temperature of ice is below freezing point, the rays which are absorbed will no doubt produce dilatation; but during summer, when the ice is not below freezing point, no dilatations can take place. All physicists agree that the rays that are then absorbed go to melt the ice and not to expand it (*Phil. Mag.*, XL. 166).

If Moseley's theory be correct we cannot understand

why the glaciers in the Arctic regions should advance in winter, and we ought to find proofs of retrogression due to winter contraction as well as of summer progress. On this theory again, why should the advance of a glacier be greater both at the top and the bottom than half way up, why more rapid in its medial portion than near its edges? Again, to quote an argument of Mr. Blake's, a glacier for purposes of this experiment is like a piece of ordinary ice, and "if one will flatten out under the influence of heat, the other ought to do. But whoever saw a block of ice bulge out under the influence of heat? If anyone has seen such a thing, or has made any experiments upon it, it would be far more to the point than theory, or if these molecular changes could go on even in a large mass of ice without any *vis-à-tergo*, surely some tendency to a definite shape ought to have been observed in icebergs which should, as the mass widens out, grow thinner and thinner."

Forbes pertinently urges that in order to account for the observed rate of the motion of glaciers by this theory, the entire mass of the Mer de Glace of Chamounix must have an average range of temperature of 4¼ Réaumur or 9½ Fahrenheit, which is quite contrary to experience. The expansion and contraction of ice by heat and cold can only take place when it is below its freezing point. If it is percolated by water it cannot rise above 32° or expand, and, as we know it is so percolated during the daytime, we cannot believe that during the night the temperature can be lowered throughout to a depth of from 300 to 600 feet of ice through a range of 9½ degrees. As a matter of fact, according to the observations of De Saussure and others, the actual range of temperature attributable to a glacier is between limits absolutely incapable of effecting the expansion of the ice in the smallest degree (*id.*, 41).

Mr. Matthews, in a paper published in the *Alpine Journal* for 1870, says :—"The whole superstructure of the

crawling theory is founded on the hypothesis of the variation in temperature of the interior of glacier ice, and until that hypothesis is verified experimentally the theory cannot be translated from the region of speculation into that of reality. To Mr. Moseley's statement, that ice if opaque to non-luminous is transparent to luminous heat, he urges that this cannot apply to those portions of a glacier above the snow line, nor to those portions of it below that line which belong to the region of *névé* which share in the movement of the general mass. Even in the region of the glacier, when the substance is actual ice itself, it is doubtful if the sun's heat penetrates many inches. The surface bears a great resemblance to the upturned edges of a pack of slates, and it becomes very opaque as it disintegrates with the sun's heat. Nor would the sun's rays reach those portions of a glacier covered with moraine and rubbish. In such parts, therefore, the motion ought to be greatly diminished or to be entirely arrested. If ice dilates with heat like lead, there must be a point above which it does not expand, and where its own motion will be nil. Above this point, if it is below the summit level, the glacier will move uphill or be crushed in its attempt to do so, and below it, each point will move with a velocity proportional to its distance from the point at rest, which is contrary to all experience" (*Alpine Journal*, 1870, 421).

Mr. J. Ball, in the *Philosophical Magazine* for July, 1870, urges that a glacier cannot move *en masse* by expansion and contraction, since it is not a solid mass, but cut up into sections by crevasses much deeper than the depths affected by external changes of temperature. Again, all the experiments (notably those of Agassiz) point to the interior of a glacier having a more or less constant temperature, and not being subject to great variations; its surface being coated with a nearly opaque crust, protects its interior from any but trifling influences of luminous heat. The winter cold does not

penetrate the surface more than a moderate number of feet, and that of the night scarcely as many inches. Again, if his theory be true, a glacier ought to progress at a rate proportional to its length, which it does not. In winter glaciers are covered with snow, which protects them against the effect of radiant heat, but in winter, glaciers move on as they do in summer, only at half the pace. How, again, by such a theory, can we account for the differential motion between the centre and the sides of a glacier? (Ball, *Phil. Mag.*, XL. 1—10).

After Canon Moseley's death his theory was revived by Mr. Brown, in a paper read before the Royal Society (*Proceedings*, Vol. XXX.). In this he somewhat modified the original view, in order to meet objections, and urged that the contraction and expansion of the surface layers of a glacier drag the lower layers after them, and cause the upper layers to shear over those below them. To this particular argument it may be urged that the notion, that the contraction and expansion caused by diurnal variation of temperature on an Alpine glacier, which directly affects only two or three feet of its surface, can influence its motion for a thickness of several hundred feet, is assuredly extravagant. Again the recurrence of crevasses must prevent the contraction between portions of the surface layer at any considerable distance from one another (Trotter, *Proceedings Royal Society*, XXXVIII., 93). This concurrence of evidence seems to put Mr. Moseley's theory, which a few years ago was advocated with so much pertinacity and success, out of court altogether, nor do I know that it retains any supporters. Let us now turn to another theory, which still has some adherents.

In the year 1845 Mr. Sutcliffe communicated to the *Philosophical Magazine* a paper on a theory of glacier movement. In this paper he proposed to reconcile the apparent contradiction between the observed action of

glaciers and the apparently rigid nature of ice by postulating that heat is actually developed in glaciers by the intense local pressure in their interior. This heat, he urges, must create temporary fluidity at points and surfaces where the compressing force is a maximum, thereby allowing the particles to slide into new positions, until when, released from the excess of pressure, the mass instantly resumes its rigidity. He argues also that pressure without heat may tend to reduce ice to fluidity. From the fact of water being denser than ice it follows that, if water were cooled down below the freezing point while subjected to pressure, it might be found to remain permanently fluid, whence it would be fair to presume that pressure sufficiently great would restore ice to the more compact form of fluid water. He concludes by suggesting this fact as a possible *vera causa* of the motion of glaciers (*Phil. Mag.*, XXVI. 495—7). This paper, which is very interesting and suggestive, has been largely overlooked. It in fact propounds as an hypothesis a view put forward by Professor James Thomson many years later with considerable force.

That investigator argued in a paper published in 1849, that the lowering of the freezing point of water ought to amount to ·0075° centigrade for every additional atmosphere of pressure. His conclusion was experimentally proved by Sir Wm. Thomson in 1850.

On the basis of this as a postulate, Professor Thomson, in 1857, went on to argue that, "if a mass of slightly porous ice containing water diffused in it at 0° centigrade, be subjected to forces tending to change its form, it will have its melting point lowered below 0° centigrade, and will therefore begin to melt and in liquefying evolve cold; the liquefied portions being subjected to squeezing of the compressed mass in which they originate, will spread themselves out through the pores of the general mass by dispersion from the regions of greatest to those of least fluid pressure. This

will relieve the pressure where the compression and liquefaction of the ice takes place; on the removal of the pressure the water will be frozen by the cold liberated, as already mentioned; the water thus freezing in a new position will cause a change of form, and a plastic yielding of the mass of the ice. The yielding of one part leaves another part free from pressure, and that acts in a similar manner, and on the whole a continual succession goes on of pressures being applied to particular parts, liquefaction in those parts—dispersion of the water so produced, in such directions as will relieve its pressure, and recongelation by the cold previously evolved, of the water on its being relieved from this pressure. The parts recongealed after having been melted must in turn, through the yielding of other parts, receive pressures from the applied forces, thereby to be again liquefied and to enter again on a similar cycle of operation."

Professor Thomson adds a note to the effect that the case is not limited to ice originally porous. If ice be kept at or above 0° centigrade, then as soon as pressure is applied to it, pores occupied by liquid water must immediately be formed in the compressed parts, and no part of the ice, however solid, can resist being permeated by the water squeezed against it, which by its pressure must cause melting to set in, thereby reducing it to a porous condition (*Phil. Mag.*, 4th ser., XIV. 549—550).

The objections to this theory, countenanced as it has been by some great names, including Helmholtz, are insuperable. Thus, as Mr. Brown urges, "its advocates hardly seem to consider how very small the lowering of the freezing point is for any ordinary pressure. It is only ·0075 per atmosphere. In other words, it will require a pressure of 2,000 lbs. per square inch to liquify ice at 31° instead of 32°. This is equivalent to the weight of a column of ice about 5,000 feet high. It is needless

to ask whether such a pressure can exist within an ordinary glacier, while, on the other hand, glaciers undoubtedly move at temperatures far below the freezing point, in the arctic regions below zero" (*Proceedings Royal Society*, XXXIV. 211—212).

Professor Tyndall has also proposed some acute criticisms of this theory. He first urges that the water in the supposed case, when escaping, would escape upwards as surely as downwards, since the tendency to flow down by its own gravity would be slight compared with the other forces acting on it, and the ice above the melting portion would be less dense and more permeable than that below it, and the glacier ought to move uphill instead of down. Again, as Tyndall says: "The difference between the length of the Mer de Glace at Montanvert, and at the summit of its principal tributary, the Col du Géant, is about 4,846 feet. An atmosphere of pressure is equivalent to about 40 feet of ice, which, according to Professor Thomson, would lower the freezing point of water by ·0075 of a degree Centigrade. This being so, the pressure of the whole column of ice referred to, 4,846 feet, would lower it nine-tenths of a degree. "*Supposing then*," as Tyndall says, "*the unimpeded thrust of the whole glacier, from the Col du Géant downwards*, to be exerted on the bed at the Montanvert, or in other words, suppose the bed of the glacier to be absolutely smooth and every trace of friction abolished, the utmost the pressure thus obtained could perform would be to lower the melting point of the Montanvert ice by this quantity. Taking into account the actual state of things, the friction of the glacier against its sides and bed, the opposition which the three tributaries encounter in the neck of the valley at Trélaporte, the resistance encountered in the sinuous valley through which it passes; and, finally, bearing in mind the comparatively short length of the glacier, which has to bear the thrust, and oppose the latter by its friction only, I think it will be evident that

the ice at Montanvert, cannot possibly have its melting point lowered by pressure more than a small fraction of a degree." Tyndall then goes on to urge that his experiments in the winter on the surface ice of the Mer de Glace shewed considerable movement at $-5°$ centigrade, when it would require 667 atmospheres of pressure to melt it, equivalent to a column of ice 26,680 feet, or to a height two and a half times that of Mont-Blanc above the Montanvert, whose portentous summit must have been connected with it by a continuous glacier, with its bed absolutely smooth to secure the requisite pressure (*Glaciers of the Alps*, 342—345).

Lastly, it seems to me, Professor Thomson's theory fails to meet the difficulty that the motion of a glacier is differential, that its centre moves faster than its sides, and its surface more than its base; that is, that the motion is greatest where the pressure, and therefore the postulated liquidation, is least.

Let us now turn to Dr. Croll's theory, which, like all his theories, has the advantage of being ingenious and of endeavouring frankly to meet the conditions of the problem. In a paper he published in 1870 he took for granted that Mr. Moseley's experiments on the shearing of ice, to which reference will be made presently, were conclusive against the notion that ice is a plastic substance. His words are, "Unless some very serious error could be pointed out in the mathematical part of his investigation, it would be hopeless to overturn his general conclusion as regards the received theory of the cause of the descent of glaciers, by searching for errors in the experimental data on which the conclusion rests" (*Phil. Mag.* XL. 154).

He, on the other hand, saw clearly that none of the theories already described would account for the differential motion of glaciers as proved by numerous experiments, and that unless this difficulty could be explained it was useless to produce a theory, however ingenious. He accordingly appealed to a

modification of the theory of Sutcliffe and of Thomson, which I had better state in his own words. "It is found," he says, "that the rate at which a glacier descends depends upon the amount of heat which it is receiving . . . . . heat assists gravitation to shear the ice not by direct pressure but by diminishing the cohesive form of the particles, so as to enable gravitation to push the one past the other. . . . There seems to be but one explanation, namely, that the motion of the ice is molecular. The ice descends molecule by molecule. . . . . The passage of heat through ice, whether by conduction or radiation, is in all probability a molecular process, that is, the form of energy termed heat is transmitted from molecule to molecule of the ice, a particle takes the energy from its neighbour and passes it on, but a particle must be in a different condition when in possession of the energy, to what it is before and after. Before it was in a crystalline state it was ice, and after it will be ice, but at the moment it is in possession of the passing energy it becomes water. We know that the ice of a glacier in the mass cannot become possessed of energy in the form of heat without becoming fluid. May not the same thing hold true of the ice particle" (*Phil. Mag.*, XL. 168—9).

He urges, in effect, that the shearing force of the particles of ice when heat is passing through them is not constant, and "that while a molecule of ice is in the act of transmitting the energy received, it loses for the moment its shearing force if the temperature of the ice be not under 32° F." Consequently a molecule, directly it assumes the fluid state, is completely freed from shearing force, and can descend by virtue of its own weight without any impediment. All that the molecule requires is simply room or space to advance in. If the molecule were in absolute contact with the adjoining molecule below, it would not descend unless it could push that molecule before it, which it probably would not be able to do. But the molecule actually has room in

which to advance; for in passing from the solid to the liquid state its volume is diminished by about one-tenth, and it consequently can descend. But when it again assumes the solid form, it will regain its former volume; but the question is will it go back to its old position. If there were only this one molecule affected by the heat, this molecule would certainly not descend; but all the molecules are similarly affected, although not all at the same moment of time. At the lower end of a glacier a molecule receives heat from the sun, melts, losing its shearing force, descends by its own weight, and contracts. The next molecule above it is then at liberty to descend, and will do so as soon as it assumes the liquid state. The former molecule has meanwhile become solid, and again fixed by shearing force, but it is not fixed in the old position, but a little below where it was before. If the second molecule has not meanwhile melted from heat derived from the sun, the additional supply it will receive from the solidifying of the first one will melt it. It will then immediately descend till it reaches the first molecule, when it in turn becomes solidified, and so the process goes through the glacier, which is consequently in a state of constant motion downwards" (*Phil. Trans.*, XXXVII. 201—204).

To this exposition of Mr. Croll's theory, Mr. J. Burns replied in the *Geological Magazine* for 1876: "It seems strange," he says, "that a molecule A should on freezing give its heat to B, from which it is some distance removed, and should impart none to the molecule on which it rests, or to those on either side, but supposing the molecules to be perfectly accommodating in this respect, their downward progress is only helped by heat passing along the glacier from its lower end upwards. Let us take the molecules A, B, and C, somewhere within or on the surface of the glacier. Supposing B now is melted by the sun. When a solid, it was in contact with both A and C, and therefore on

melting it cannot move. True, when liquid it is reduced about one-tenth in size, and in consequence its centre may move a small fraction of its diameter towards A; but on freezing again it must resume its original position. A or C now gets the heat, melts, oscillates, and freezes in its old position; and so on. From such heat there is plainly no molecular motion." Even if we were to modify Mr. Croll's theory so as to make the freezing of one particle synchronous with the melting of its neighbour, we should secure only the smallest imaginable molecular motion. In reference to the denuding power of glaciers, which Mr. Croll explains as due directly to the stones and other hard matters embedded in them and propelled along by the molecular movement he appeals to, Mr. Burns replies forcibly there could not be a weaker denuding agency than a great glacier which as a solid mass is stationary, but on whose interior and on whose surface liquid molecules are here and there moving through infinitesimal distances . . . . and will a stone that is held in the crystalline grasp of millions of ice molecules be forced along by a few dozen water molecules trickling through a fraction of their diameter along its surface. A stone thus 'forced along,' may be supposed to scoop out valleys if the exigencies of geologists demand it, but the force that moves the stone would not serve to tickle the sole of a mite .... The motion of the molecules within a glacier can no more cause a thrust than the rise of the sap within a tree in spring can pull it up by the roots."

Dr. Croll did not answer this attack, but in a subsequent paper he professes to have abandoned the views he originally propounded on the subject, and to have modified his position considerably. In this paper he says: "Ice is not absolutely solid throughout. It is composed of crystalline particles, which, though in contact with one another, are however not packed together so as to occupy the least possible space, and even though they were, the particles would not fit so

closely together as to exclude interstices. The crystalline particles are however united together at special points determined by their polarity, hence, as Professor Tyndall remarks, the reason why volume for volume ice is less dense than water . . . When a crystalline molecule melts, capillary attraction will cause it to flow into the interstices between the adjoining molecules. The moment it parts with the heat received it will resolidify, but not so as to fill the cavity it occupied in the fluid state. The liquid molecule in solidifying assumes the crystalline form, and as the interstice in which it solidifies will be too narrow to contain it, the result will be that the fluid molecule, in passing into the crystalline form, will press the two adjoining molecules aside in order to make sufficient room for itself between them, and this it will do, no matter what amount of space it may possess in all other directions. The crystal will not form to suit the cavity, the cavity must be made to contain the crystal, and what holds good of one molecule holds true of every molecule which melts and resolidifies. The process is therefore going on incessantly in every part of the glacier, and in proportion to the heat which the glacier is receiving. This internal molecular pressure, resulting from the solidifying of the fluid molecules in the interstices of the ice, acts on the mass of the ice as an expansion force, tending to cause the ice to widen out in all directions."

This is the theory of the mechanism of ice motion as finally developed by Dr. Croll. It has been sifted with critical skill and acumen by the Reverend J. F. Blake, in the 3rd volume of the *Geological Magazine*, p. 493, and so far as we can see has been completely shattered by him. At all events his analysis has never been met in any way. As Mr. Blake so well shewed, in speaking of crystalline molecules and liquid molecules of the same substance as if they were different in size or shape, Dr. Croll used language without meaning in physical science; a molecule is the

ultimate factor to which we can reduce any piece of matter, and being so, is absolutely unalterable in shape and in size, we cannot divide it or alter it without constituting a new substance altogether. The different forms assumed by each substance are not due in any way to an alteration in its ultimate factors, namely, its molecules, but to the re-arrangement of these same molecules. We cannot, as Dr. Croll does, speak of the melting of a crystalline molecule, and of its flowing into the interstices between adjoining molecules, nor can we speak of a liquid molecule solidifying and assuming the crystalline shape. This language, and the whole induction based upon it, ignores entirely the real nature of molecules. If we put aside this fundamental contradiction, and understand Dr. Croll as referring not to molecules but to the minute particles which are aggregated together in al masses of ice, each particle consisting of a congeries of molecules, which when it melts are loosened, we are no nearer a rational solution of our difficulty.

Suppose we grant that, in melting, these particles lose their polarity and arrange themselves so that they get better into the spaces between those forming part of the crystalline substance, and better also among themselves, so that on the whole they occupy less room than before, Mr. Croll seems to argue that in solidifying these particles will find the spaces or interstices in which they solidify too narrow for them, and must consequently squeeze their neighbours asunder, and thus cause the ice to expand. To this Mr. Blake replies: "Is the fragment or particle of ice to which the argument is applied divisible or indivisible under the ordinary forces of nature? If divisible, why does it not flow into *several* interstices, and get squeezed into more in the act of solidifying, and make several small crystals instead of one bigger one? If indivisible the main mass would remain in the original cavity, and could only crystallise by coming back together, or by the main mass

coming after the minute portion that had got entangled in an interstice. Again, why should not in every case the molecules whose attachment is loosened by melting go back to their old place in solidifying?" "Unless some new force is brought into play," says Mr. Blake, "on the instant, whatever old forces they overcame originally in the act of crystallising the first time, they can certainly overcome again none that Mr. Croll mentions. Gravity always acted, and the molecular forces of crystallization are just as competent to push back the molecules against it as they were before when first the ice was formed" (*Geol. Mag.*, 1876, 495—6).

"There is nothing," he continues, "in Mr. Croll's theory, to distinguish a glacier from an ordinary piece of ice, and if one will flatten out as he supposes, the other ought to do so too. But, whoever saw a block of ice bulge out under the influence of heat? Again, Mr. Croll, in arguing about a small portion of ice melting and then resolidifying, and passing its heat on to the next, and so on, seems to ignore the elements of latent heat and of conductivity in ice. Before a particle of ice can melt, it must first be brought to the melting point, *after which* so many units of heat must be added to it in order to melt it. Suppose a melted particle in the midst of ice colder than at melting point, its heat would be distributed in raising the temperature of the surrounding ice, according to its conductivity, and what was left would be insufficient to melt any other particle of its own size. Hence, before the solidifying of one particle could be sufficient for melting another, the whole surrounding mass must be at melting point, and there must further be some cause for the devotion of the spare heat to one particular particle, to say nothing of the cause which is to bring about a perpetual doing and undoing of the same operation. If there could be any such passing on of a melted state through a body to the other end, we ought to see a glass rod held in the fire melting at the end away

from the fire, or does the outside particle refuse to melt? A candle, too, ought to melt in the socket instead of near the lighted wick, and to bulge out into abnormal obesity. When heat is applied to ice the heated side is first raised to the melting point, and as we recede from that side the temperature gradually diminishes. If more heat is applied it is spent in keeping up this state of the ice as to temperature against all possible losses, and in melting that part of the ice nearest to it. No amount of this additional heat will alter the state of the interior, except so far as it may alter the *other* conditions on which it depends. . . . . No amount of internal heat could possibly bring about internal melting in a uniform mass of ice. It is simply a myth" (*Id.* 497).

Again, as Heim says, Croll neglects the fact that ice is transparent to heat rays to some depths; but when we have considerable thickness, as on a glacier at 0° of temperature, the heat rays are not transmitted, but go to melt the surface layers. Croll's theory does not account for the quicker progress of the centre than the sides of a glacier, nor for crevasses, etc., etc. (Heim, 308).

Again Croll's theory requires that his glacier shall be at the temperature of 32°, whereas we have every reason to believe that it is much below that temperature during a large part of the year, not only on account of the rarefied atmosphere in which it lives but the continual radiation from its surface at night and evaporation at all times, and except in its lower layers, when the glacier is constantly passing into a liquid form, it is most improbable that the temperature in any part of a glacier is so high as 32°. It cannot be urged that when a minute crystal of ice melts, the liquid thus formed drains away between the interstices of its neighbours, or we should have every slab of ice subject to solar rays sweating away its substance from its nether surface, which is not the case. So far as

we can experiment, we find that the sun's rays acting on a mass of ice melt its surface layers, and they flow away by gravity, or remain as tightly enclosed by the nether ice where gravity cannot work as water in a well-puddled reservoir does. But Dr. Croll ignores this every-day melting of ice altogether, and introduces us to a transcendental method.

This completes the roll of the various theories which have been forthcoming to account for the motion of glaciers independently of gravity, and it must be admitted that they all fail to reconcile themselves to the ordinary laws of physics, and fail, therefore, to secure for themselves a place among the postulates of empirical science. Let us now turn to the theories which in various ways invoke gravity as the chief motor in glacier motion.

We will begin with the earliest of these theories, namely, the sliding hypothesis.

It was first scientifically stated by G. S. Gruner, in a work published at Berne in 1760, entitled *Beschreibung des Eisgebirges der Schweizerlandes*. In this he refers to the fact of stones on the back of the glacier at Grindelwald having been seen to move gradually down, so that a stone had been noticed to advance 50 paces in six years, and urges that the whole mass of ice which is embowered in the valley moves down *en masse* by its own weight. This movement, he argues, is assisted by the greater humidity of the nether surface of the glacier.

Deluc the elder somewhat modified Gruner's position. He argued that great caverns and hollows are formed underneath glaciers which are thus supported on a kind of ice pillars, when they give way the ice mass gives way, and its tendency is to move down the slope on which it rests. "This," he says, "causes the march down of great masses of ice called glaciers. They do not slide down *en masse*, but piecemeal, the pieces or fields of ice being separated by crevasses

which close up as the hinder field overtakes the one in front, and the one in front pushes before it the earth as it advances." Our author writes very modestly, however, and confesses that the subject is full of difficulty (*Lettres Physiques, etc.* The Hague, 1778, vol i. 140—142).

De Saussure, to whom the sliding theory is generally attributed, no doubt discovered and published it independently, but later, in his work, *Voyages dans les Alpes*, of which the first volume was published in 1779. His statement of it I translate as follows: "Another cause which prevents the excessive growth of the snow and ice is their weight, which presses them more or less rapidly into the valleys where the heat of the summer melts them. The descent of the snow in the form of an avalanche is a known phenomenon to which we shall return. That of the ice, which is more gentle and generally with less noise, has been less observed. Nearly all glaciers, as well of the first as of the second kind, rest on inclined beds, and all those of more than a certain size have beneath them, even in winter, currents of water which flow between the ice and the bed which supports it. It can be understood, therefore, that these frozen masses, following the inclined bed on which they rest, separated by the water from their attachment to the ground and sometimes supported by the water, must slide little by little and descend, following the inclination of the valleys. It is this gradual but continuous sliding of the ice on its inclined bed which moves it into the low valley."

These sentences contain what De Saussure had to say about the motion of glaciers, and it will be seen that both he and his predecessor, Gruner, contented themselves with the supposition, to use the words of Principal Forbes, "that the mass of the glacier is a rigid body sliding over its trough or bed in the manner of solid bodies."

This view was maintained by De Saussure's followers, notably by Ramond, Kuhn, etc., who all apparently treated

glacier motion as a motion *en masse* caused by gravity, due partially to their own weight, partially to the pressure of the higher ice and *névé* (see Studer, *Lehrbuch*, 1844).

Forbes summed up his arguments against this theory thus: "If the glacier slides down its bed, why is not its motion continually accelerated, *i.e.*, why does it not result in an avalanche? and is it not inconceivable that a vast and irregular mass like a glacier, having a mean slope of only 8° and often less than 5°, can *slide*, according to the common laws of gravity and friction, over a bed of uneven rock, and through a channel so sinuous and irregular that a glacier is often embayed in a valley, whence it can only escape by an aperture of half its actual width? On all mechanical principles, we answer, that is impossible. We may add that many small glaciers are seen to rest upon slopes of from 20° to 30° without taking an accelerated motion; and this is conformable to the known laws of friction. It is known, for instance, to architects that hewn stones, finely dressed with plane surfaces, will not slide over one another until the slope exceeds 30° (*Forbes' Travels*, 35).

He says further "there is no reason to suppose that either Gruner or De Saussure thought it necessary to take into account the varying form of the channel through which the glacier had to pass, and the consequently invincible barrier presented to the passage of a rigid cake of ice through a strait or narrowed aperture where it occurred" (*Phil. Trans.*, 1846, p. 137).

Hopkins, who resuscitated De Saussure's theory in another form, in replying to Forbes, denied that the bed of a glacier is rough and rugged; "how," he says, "could the hardest rocks resist for thousands of years the increasing effects of infinitely the most powerful polisher that nature has put in action; the fact of the existence of *roches polies* at the end of a glacier and the continuation of glacier valleys proves uncontrovertably that there is some sliding

in glaciers," and he urges that the surfaces of rocks forming the beds of glaciers must necessarily be free from asperities.

He further showed, experimentally, that, while it is perfectly true that a smooth hard body will not descend down an equally smooth hard plane at angles considerably greater even than that at which some glaciers are formed, ice nevertheless does so; and he argues that whereas the particles of ice in contact with the plane are capable, so long as they remain a part of the *solid* mass, of exerting a considerable force to prevent sliding, they are incapable of exerting any sensible force when they become detached from the mass by the liquefaction or disintegration of its lower surface, and he contended that the essential condition of glacier motion is that its lower surface is kept continually at or near zero by the conduction of heat from the earth's crust, which is proved by the flow of water from underneath all points of glaciers (*Phil. Mag.* XXVI. 1—16).

Hopkins also proved experimentally that the argument of Charpentier and Forbes as to the motion of a glacier, if it moved *en masse*, being an accelerated motion, is only true of angles greater than that whose tangent determines the co-efficient of friction between the glacier and its bed; and he further shewed that, for inclinations not exceeding 9 or 10, the motion of a moving mass of ice is approximately proportional to the inclination of the slope on which it rests, and that such velocity is increased by increase of weight, and he succeeded in establishing that *sliding due to gravitation* is a real and very important element in glacier motion. It seems quite clear that the scratching of the bed and sides of the valley by stones enclosed like planes in the mass of the ice, and the polishing of large surfaces and the rounding of inequalities, shows that in regard to a portion, at all events, of its work, a glacier acts as a rigid body propelled by gravity.

The chief substantial objection against the theory that it moves entirely *en masse* is, that the motion of its different parts is not uniform, but, on the contrary, there is a differential motion by which its centre moves faster than its sides, and its surface layers faster than the bottom, and this motion is continuous from day to day, and is not made by fits and starts; so that, granting that a certain movement *en masse* takes place, this can only explain one portion of the problem, the greater portion of it remains unexplained. A similar objection applies to the modifications of the sliding theory propounded by Mr. Mallet and M. Martins.

The first of these was published in a paper read before the Geological Society of Dublin in 1838 by Mr. Robert Mallet. He affirms that the *primum mobile* which causes the movements of glaciers is hydrostatic pressure acting between them and the rocky bed on which they rest, and thus at intervals lifting them up and floating them, or, as it were, transferring them upon liquid rollers from a higher to a lower level. He goes on to argue that the bed on which a glacier rests is always warmer than the glacier itself, whence the bottom of the glacier is always melting, thus accounting for the torrents which underlie it. This sub-glacier melting, he urges, goes on irrespective of season or climate. In summer the stream is also fed by the melted snow and ice of the surface, the water from which finds its way below by the many fissures. These waters find a ready vent in summer, and, according to Mr. Mallet, the glacier would not move at all in that season but for certain disturbing causes. But to give his own words: "When winter has covered its whole expanse many feet deep in snow, and when the embouchure of the sub-glacial streams is also gelid, and partially, or sometimes wholly stopped, the waters rising and pent up beneath the bed of the glacier, lift its mass more or less from off the base on which it rests, and with more or less regularity according to

the variety and size of the several segments into which it is divided by the crevices, until at length a sufficient change of position is effected to permit the escape of the imprisoned waters, when these, rushing forth, empty the icy caverns which they had filled, and the mass of the glacier, whole or in parts, descends by a certain distance into the valley. The motion cannot hence be uniform, but *per saltum*, which is found to be the general fact, though often difficult of observation" (*Trans. Dub. Geol. Soc.* I. 319—320). This operation, Mr. Mallet argued, was facilitated by the ice being of less specific gravity than water, and he urges that, when the glacier was raised by hydrostatic pressure, it was so in a direction perpendicular to its bed, but, when by the withdrawal of the water it was again deposited, it would rush in a direction perpendicular to the horizon; hence the cause of its motion (*id.*, 321). By means of this theory Mallet professes to account in an ingenious way for many of the phenomena of glaciers. The theory, I need not say, is no longer held by anyone, although it hardly deserves so severe a criticism as was passed upon it by Charpentier, when he says of it:—"Voilà une explication qui a besoin de commentaire, mais non pas de refutation" (*Essai sur les Glaciers*, 38 note.) This sharp phrase is due to the fact that he altogether misunderstood the argument of the ingenious Irish writer. It is answered completely, however, by an appeal to the fact that glaciers have been clearly shewn not to move by jerks and jumps, but continuously in winter and in summer, and also that they have a continuously differential motion. While his main theory no longer lives, we must not forget that it was Mallet who first, in the paper just cited, noticed that the transverse crevasses in glaciers have a curved form with their convex side presented downwards, and in the direction of the glacier motion (*op. cit.*, 321), and he urged that the central parts of a glacier must descend much more rapidly than its lateral

ones (*id.*, 328). This most important generalization, which has been amply confirmed since, was the first step in a truly scientific theory of glaciers based upon experimental and not upon *a priori* methods.

M. Martins proposed another modification of De Saussure's theory. He states his theory thus: "In summer, immense transverse crevasses divide the entire mass of the glacier vertically into so many secondary wedge-shaped masses; consequently its surface is increased by the sum of all the spaces which the crevices leave between them at their upper part. The glacier resting firmly against the mountain cannot be pushed backward; it is, therefore at its lower part when nothing arrests it, that it becomes displaced and moves forward. The winter following, these crevices are filled with snow, blown into them by the winds, or falling in the form of avalanches. This snow becomes ice under the alternate influences of melting and freezing during the months of May, June, September, and October. In the succeeding summer months new crevices are formed, the glacier advances, and so on successively. This progression is therefore neither a slipping nor a sinking (both of which it is difficult to admit, since the ice must adhere to the ground), but a successive dismemberment (*Ed. Phil. Jour.*, 30. 294).

Besides the objection that we now know, that the movement of glaciers is continuous and not by jerks, Forbes adds, that it is universally admitted that the glacier proper does not grow by the consolidation of snow in its fissures (*Theory of Glaciers*, 101).

The views of De Saussure were revived and modified, as I have mentioned, by a physicist of the first rank, in the person of Mr. W. Hopkins. In his modification of the theory, he got over the difficulty of the differential motion by a somewhat ingenious argument. In his paper published in the eighth volume of the *Cambridge Transactions*, he

pressed the view that the friction of the ice against the sides of the valley produces a dislocation of the glacier into longitudinal stripes, and as a result the central portions slide past those adjacent to them, and so on for successive strips as we approach the sides, the more rapid retardation near the sides being rendered mechanically possible by the increased number of these longitudinal dislocations. The result in such a case, it was argued by Hopkins, would be that the ice would advance by *échelons*, or that strips of ice of a certain number of feet, or yards, or fathoms, would move either suddenly or by gradual sliding, but at all events so as to mark by an abrupt separation at the longitudinal fissure, that the one portion of the ice had slipped past the other by a distinct measurable quantity.

In regard to this notion of a glacier being a congeries of moving masses, Forbes maintains that a rugged channel like that of a glacier being packed with angular solid fragments would speedily be choked, and that further pressure from behind would tend to wedge the fragments more tightly. . . . and if the figure of the channel be irregular *i.e.*, have expansions and contractions, however smooth its surface, and however small the sliding angle, the choking of a strait or contraction by the piling of the fragments will be as complete as if the lateral friction were excessive. This points to the impossibility of the discharge of a fragmentary solid through a gorge by long strips fractured parallel to its length, and constituting parallelopipedons of a certain breadth; secondly, he urges that actual observation proves that a glacier is not a mass of fragments or parallelopipedons, as some have supposed. Most of the crevasses at a small depth shrink to mere slits, and perhaps disappear altogether, and the area they occupy is small compared with that of the unbroken ice, and when viewed as a whole, is capable of conveying strains as thrusts, its cohesion is no more destroyed than a parchment sieve is

incapable of being stretched because it is covered with fine slits. Again, it is seldom the crevasses intersect even when most numerous, and they do not therefore separate the whole mass into blocks or fragments, and when they do so, it would seem that they are very shallow, causing only a surface dislocation or they would fall away in avalanches.

Were, he says, the inequality of the central and lateral movement of the glacier mass to be attributed to longitudinal fissures or discontinuities, by means of which broad strips of ice slide past each other, we should have to demonstrate the existence of such fissures, which could not be always close unless either (1) the surfaces were mathematically adapted to slide over one another, or (2) the ice possessed sufficient plasticity to mould the surfaces to one another's asperities, in which case the plasticity would alone be sufficient without the discontinuity, to explain the motion of the ice. These longitudinal fissures, cutting the common transverse fissures perpendicularly, would divide the glacier even where most level into trapezia, and no transverse crevasse could be straight edged, but must be jagged like a saw, or cut *en échelon*. Such a phenomenon never occurs unless where a glacier is moving *torrentially* or with great disturbances, and down a steep. *There* such longitudinal fissures may occasionally be seen, but they form the exception and not the rule. It has been demonstrated by an elaborate proof, that the only trace of longitudinal discontinuity in the normal condition of the glacier is to be found in the veined structure, which, being caused by a partial discontinuity at a vast number of points, admits of an insensible deformation of the glacial mass without sudden or complete rents, or slips, or the formation of zigzag crevasses (*Phil. Trans.*, 1846, 197).

In the course of this controversy Mr. Hopkins urged that both the sliding and the viscous theories, that is his own and Forbes's theories, agree in assigning gravity as the primary cause of glacier motion, but in the one

case the efficiency of gravity is principally due to the state of disintegration of the lower surface of the glacier, while in the other it is maintained that its efficiency is due to the plasticity of the general mass. He does not deny that ice may be partially plastic, but while admitting this he urges that much the greater portion of the movement is due to sliding. He also, with singular fairness, appeals to further experiment as the real test, and he states that the observations required are such as will determine, as far as possible, the relative motions of the upper and lower surfaces of a glacier, and he admits that if experiment proves the motion of the upper part of a glacier to bear a large ratio to that of the lower surface, the claims of the viscous theory must be at once admitted (*Phil. Mag.*, 1845. XXVI. 247—250). The test last mentioned was again appealed to by Mr. Hopkins in a later paper, in which he says: "The ultimate test of the sliding and plastic theories must be sought in observations on the relative motions of the upper and lower surfaces of a glacier. The claims of the two theories would thus be decided beyond dispute. Accurate observations are also required to ascertain the form which a *continuous* straight line drawn on the surface of a glacier and perpendicular to its axis will assume by the more rapid motion of its central portion. Will it be deformed into *a continuous* loop or into a a *discontinuous* one. Such observations would decide the degree in which the greater central motion is due to the flexibility or plasticity of glacial ice, and the degree in which it is attributable to the dislocation of the general mass. Observations of both kinds are become essential in the present state of glacial theories, and would do much more towards settling the question at once respecting the cause of glacial motion, than any further controversy." (*Phil. Mag.*, XXVI. 599). The appeal was not declined by Forbes.

In 1845, he made some detailed experiments upon the respective motion of glaciers at their surface and base. He made elaborate measurements on the terminal face of the Glacier des Bois at points 8, 54, and 143 feet respectively, above the bed or floor of the glacier. The result confirmed his anticipations, that the effect of friction in retarding motion is most sensible the nearer one gets to the base. The measured motion of the three points was as follows:—

Feet.	Feet.	Feet.
2·87	4·18	4·66

being after the ratio of 1·00 2·46 and 1·62.

These results were confirmed by measurements made by MM. Dollfuss and Martins, and published in the *Comptes-Rendus* of the Academy, for October 26th, 1846. Their measurements were made on the lateral face of the glacier, and the two sets of measurements combined exactly with the demand made by Mr. Hopkins in the paper already cited. Forbes also shewed, by careful measurements with the theodolite, that the motion of a glacier is perfectly regular and continuous from point to point, and leaves no room for jerks and jumps, such as Hopkins had postulated.

Forbes's experiments may be supplemented by an easy appeal to another kind of evidence. As Dr. M. Williams says: "Crevasses of considerable magnitude are commonly formed without severing one part of a glacier from another. They are usually V-shaped in vertical section, and in many the rupture does not reach the bottom of the glacier. Very rarely indeed does a crevasse cross the whole breadth of a glacier in such a manner as to completely separate, even temporarily, the lower from the upper part of the glacier" (*Quarterly Journal Sc.*, VII. 221). This shews that the upper part of the mass of ice has a greater tension, and moves faster where the tension is removed than the lower. In fact, a glacier is literally a frozen river, and just as the water near the banks of a river is dragged and stopped by

friction, its chief motion being in its surface layers, so is a glacier. No doubt the subjacent streams tend to lubricate the ice mass in a measure, doing it more in the day than at night, in summer than in winter, there being then more water available from the melting of its surface. They would do so more if they occupied the whole of its foundation instead of only a part, but this is largely counterbalanced by the tremendous weight of the mass.

It is time that we should now turn to Forbes's own view, namely, the theory that ice, notwithstanding its apparent rigidity, is really of a plastic nature, and that a large part of its motion is due to this quality.

The first person who suggested this was apparently Bordier, who, in 1773, published a work, entitled, *Voyage pittoresque aux glaciers de la Savoie*, in which he compared ice to soft wax, flexible and ductile to a certain point, and he attributed to it sufficient ductility to enable it to move down from high ground to low (see Tyndall, *Glaciers*, 133-4). He was followed many years after by Captain Basil Hall, who, in his work called "Patchwork," describes the glaciers of Miage. He argues that when the successive layers of snow, often several hundred feet thick, are half melted by the sun, and by the innumerable torrents which are poured upon them from every side, to say nothing of the heavy rains of summer, they form a mass, not liquid, indeed, but such as has a tendency to move down the highly inclined faces on which it lies (*op. cit.* I., 104). Later, in the same work, he compares a glacier with a lava stream, and says, they are more or less frozen rivers; they both obey the law of gravitation with great reluctance, being eventually so sluggish that, although they both move along the bottoms of valleys with a force well nigh irresistible, their motion is sometimes scarcely perceptible (*id.*, III., 118).

Canon Rendu in his *Théorie des Glaciers de la Savoie*, published at Chambery, in 1840, was the next to adopt this

theory. "The mass of the glacier," he says, "is in inverse proportion to the slope over which it flows. When the trough is steep, the ice is thin, and its surface is contracted; when the slope decreases and approaches to the horizontal line, the glacier fills out—it becomes like a sea, or a lake between two streams.... Nothing shows better to what an extent the glacier adapts itself to the spot on which it happens to be than the form of the glacier of Mont Dolent, in the valley of Feriet." The highest plateau is a great amphitheatre surrounded by lofty flakes of granite of pyramidal form; thence the glacier descends by a gorge, into which it is compressed; but as soon as it has passed beyond it, it widens out anew and opens like a fan: it has therefore, as a whole, the form of a sheaf contracted in the middle and spread out at the two extremities (*Voyage dans les Alpes*, II. 247). "There are a host of facts that would seem to induce the belief that the substance of glaciers enjoys a kind of ductility which allows it to mould itself upon the locality which it occupies—to thin out, to swell, to contract, and to spread as a soft paste would do. Nevertheless, when we deal with a piece of ice, when we strike it, we find in it a rigidity which is in direct opposition to the appearances of which we have just spoken. Perhaps experiments made upon larger masses would give other results" (*Rendu*, trans. by A. Wills, edited by J. Forbes, 70—71).

Again, the same author writes, "The fact of motion exists, the progression of glaciers is demonstrated; but the mode of motion is entirely unknown. Perhaps with long observations, with experiments upon ice and snow carefully made, we shall succeed in grasping it; but we are still in want of first elements..... Nothing seems to me more clearly demonstrated than the progressive motion of glaciers towards the bottom of the valleys, and nothing at the same time seems to me more difficult to conceive than the manner in which this movement is executed—a movement so slow,

so unequal, carried out on slopes of different inclination, on ground studded with irregularities, and in channels whose width varies at every moment. This is in my opinion the least explicable of the phenomena of glaciers. Does it advance in a mass like a block of marble on an inclined plane? Does it advance in broken bits like the stones which come down one after another in mountain gullies? *Does it sink down upon itself to flow along the slopes, as lava would do, at once ductile and liquid?* Do the portions which detach themselves at the edges of steep slopes suffice to impress motion upon those which repose upon a horizontal surface? I know not. Perhaps, again, we might say that in times of great cold the water which fills the numerous transverse crevasses of the glacier becoming frozen, receives its accustomed movement of volume, gives a push to its containing walls, and thus produces a motion towards the bottom of the channel in which it flows" (*id.*, 80—82). Lastly, he says: "there is between the Glacier des Bois and a river a resemblance so complete that it is impossible to find in the glacier a circumstance which does not exist in the river. In currents of water the velocity is not uniform throughout their width, nor throughout their depth; the friction of the bottom, that of the sides, the action of obstacles cause a variation in the velocity, which is undiminished only towards the middle of the surface. Now the mere inspection of the glacier is sufficient to prove that the velocity of the centre is greater than that of the sides. The whole surface is cut by crevasses, which are in general transverse to its direction. If the motion were the same throughout the mass these crevasses which cut the surface in parallel rifts would form a straight line which would be always nearly perpendicular to the two banks, but this is not so: *the general line is a curve whose convexity advances towards the bottom of the valley, a fact which can only be attributed to the greater velocity of the ice at this point*" (*id.*, 85—86).

These passages which I feel bound to quote, in consequence of the fierce polemics which have arisen about them, prove that the learned Canon, who afterwards became Bishop of Annecey, fairly grasped the main feature of glacier motion, which had been hitherto neglected, namely, its differential motion. With the modesty of a real student, he does not claim to have proved his case experimentally, but appeals to future observers, who should do so to settle the question. It was not long before the necessary experiments were made.

In the summer of 1841, Principal Forbes was invited by M. Agassiz, who was then studying the Aar glacier, to pay him a visit there. In the course of this visit he realised the necessity of applying precise measurements at different points to the movement of glaciers, so as to definitely settle what the nature of the movement was. The next year he paid a second visit to the Alps, and having made his way to the Mer de Glace at Chamounix, and having pierced a hole in the ice, and planted his theodolite in it, he proceeded to determine its position with respect to three fixed co-ordinates. These having been obtained, three marks were made on rocks, thus giving the absolute position of the point experimented upon. On returning the next day he found that the red mark first made, showed that the glacier had advanced 16·5 inches during the previous 26 hours. Thus the diurnal motion of a glacier was obtained for the first time from direct observation (*Travels through the Alps of Savoy*, 129). During the next four days Forbes satisfied himself by similar methods, (1) that glacier motion is approximately regular and continuous; (2) that it is nearly as great during the night as during the day; (3) that an increase of motion observed on the 20th, 29th, and 30th was due to the heat of the weather; and (4) and most important, that the centre of glaciers moves quicker than the sides, quite contrary to what had been supposed previously. These conclusions he communicated to Professor Jamieson in his "First Letter on

Glaciers," dated July the 4th, 1842 (see *Ed. New Phil. Jour.*, XXXII., p. 338—341), and they were amply confirmed in later experiments (*id.*, 341—345), from which it more clearly appeared that the motion was not the same from day to day and week to week. He also shewed that this variation is common to all parts of the glacier, whether compact or fissured, and that the disproportion in the movement of the centre and sides of a glacier is greatest in the lower and faster moving part of it, where it varies from one-third to one-half of the smaller velocity, and least near the origin of the glacier, where it is only one-quarter or one-fifth. The similar variation also affects the centre more than the sides. The greatest daily motion he measured was 27·1 inches.

The veined structure in ice was apparently first described by M. Guyot, in 1838, on the Glacier of Gries. He noticed below, under his feet, he says, furrows an inch or an inch-and-a-half wide, separated by ridges of harder and more transparent ice; the ice consisted clearly of two kinds, one white and melting early, the other more perfect, crystalline, and hard. Their unequal swelling caused the furrows. On looking down a crevasse, which cut the furrows at right angles and shewed a transverse section of 30 to 40 feet, the ice seemed everywhere composed of layers of white opaque and transparent ice, as regularly stratified as certain calcareous rocks, (see Huber, *des Glacier*, p. 107, quoted by Moseley, *Phil. Mag.*, 4th Ser., XXXIX, 241). Forbes described this structure, which he independently discovered, as the ribboned structure of ice.

The general course of the bands, as pictured on the surface of the glacier, is a succession of oval waves passing into hyperbolas with the greater axis directed along the glacier. The actual shape of the curves depends very much on the configuration of the glacier. In narrow canal-shaped glaciers, the lines are nearly parallel and vertical, inclining

upwards and outwards where the ice is supported by the lateral rocks. When the glacier acquires a rounded or oval contour, the lines become more or less oval in curve, and dip inwards at angles more nearly perpendicular as the centre of the glacier is approached, and may be compared to sections of inverted cones, having a common apex pointed downwards with its angles continually diminished towards the centre (*Travels in the Alps of Savoy*, 29, 160, 372, etc.).

The course of the bands being vertical they crop out at the surface, and wherever that surface is intersected and smoothed by superficial watercourses, their structure appears "with the beauty and sharpness of a delicately-lined chalcedony." This structure Forbes proved pervaded the whole body of the glacier, and wherever a vertical section was eroded by the action of water, the harder seams of ice stood protuberant, while the immediate ones, partaking of a whitish green in colour, were washed out. He subsequently found that the blue bands are due to compact ice, and the intermediate ones to the ice being frothy and full of bubbles. The structure was apparent throughout the length of the glacier, but was more developed in the neighbourhood of moraines and the walls of the glacier. That it was not the product of a single season, Forbes showed by tracing the bands across the gaping glaciers. Throughout the greater part of the glacier the bands are parallel to the enclosing walls, but near the lower extremity they change their direction and become transverse, and lean forward in the direction in which the glacier moves at a very considerable angle. Forbes argued that "the veined or ribboned structure of the ice is the result of internal forces, by which one portion of ice is dragged past another in a manner so gradual as not necessarily to produce large fissures in the ice, and the consequent sliding of one detached portion on another, but rather the effect of *a general*

bruise over a considerable space of the yielding body. According to this view, the delicate veins seen in the glacier, often less than a quarter of an inch wide, have their course *parallel* to the direction of the sliding effort of one portion of the ice over another." He goes on to quote the case of the Glacier of La Brenva, which at a point where the ice is forcibly pressed against the naked rocky face of an opposing hill is turned into a new direction, and in thus shoving and squeezing past a prominence of rock the ice developes a veined structure so beautiful that it is impossible to resist the wish to carry off slabs, and to perpetuate it by hand specimens. This perfectly-developed structure was visibly opposite the promontory which held the glacier in check, and past which it struggled, leaving a portion of its ice completely embayed in a recess of the shore behind it. Starting from this point as an origin, the veined laminæ extended backwards and upwards into the glacier, but did not spread literally into the embayed ice. They could, however, be traced from the shore to some distance from the promontory into the icy mass. The direction of laminæ exactly coincided with that in which the ice *must* have moved if it was shoved past the promontory at all. Having proved experimentally that it had so moved, he continues, "No rigid solid body can advance in such a manner, it is therefore plastic, and the veined structure is unquestionably the result of the struggle between the rigidity of the ice and the *quasi-fluid* character of the motion impressed upon it. That it is so, is evident not only from the direction of the laminæ, but from their becoming more distinct exactly in proportion to their nearness to the point from where the bruise is necessarily strongest."

In regard to the state of the crevasses formed by the laminæ, Forbes shewed them to be owing to the differential motion of the parts retarded by lateral friction, and to the fact that the friction being least where the motion is fastest,

there will be a natural tendency to molecular dislocation in a direction sloping towards the middle of the glacier. As we near the centre of the glacier, the friction due to the bed of the glacier will more and more modify the effects of that due to its walls, until the lamination will take place entirely in the vertical plain, causing the spoon-shaped arrangement of the surfaces of dislocation as observed. He then goes on to show how the phenomenon of the frontal dip is explainable by the same notion that the glacier really moves as viscous bodies move (Article, *Glacier*, in E.B., for 1855).

He urges (1) that it accords with the view of the origin of the bands, that the glacier actually does move fastest in the centre, and that the loop of the curves described coincides by observation with the line of swiftest motion. (2) That the bands are least distinct near the centre, for there the difference of velocity of two adjacent strips parallel to the length of the glacier is nearly nothing, but near the sides where the retardation is greatest, it is a maximum. (3) The less elongated form of the loops in the upper part of the glacier corresponds with the observed fact, that the difference in velocity between the centre and sides is greatest near the lower end of the glacier, and that the velocity is most uniform in the upper part. (4) In the highest parts of such glaciers, as the curves become less bent, the structure also vanishes. (5) In wide glaciers, where the velocity is nearly uniform across their breadth, no vertical structure is developed, while the friction of the base developes an apparent stratification parallel to the slope down which they fall. (6) It also follows that the frontal dip of the structural planes of all glaciers diminishes towards their lower extremity. (7) When two glaciers meet, the structure immediately becomes more developed; this is due to the increased velocity as well as friction of each, due to lateral compression. (8) The veined structure invariably tends to disappear when a glacier becomes so crevassed as to lose

horizontal cohesion, as when it is divided into pyramidal masses. This of course destroys any determinate inequality of motion, each mass moving singly (*Edin. New Phil. Journ.*, October, 1842).

In his famous fourth letter, published in the *Edin. New Phil. Journ.*, January, 1848, Forbes urges most emphatically that ice moves like a plastic body, and after quoting a number of facts in regard to the change in crevasses, inequalities, &c., he says, "all these facts, attested by long and invariable experience, prove that the ice of glaciers is insensibly and continually moulding itself under the influence of external influences, of which the principal, be it remarked, is its own weight affecting its figure, in connection with the surfaces over which it passes, and between which it struggles onwards. It is in this respect, absolutely comparable to the water of a river, which has here its deep pools, here its constant eddy, continually changing in substance, yet ever the same in form" (*id.* 34, 4). "The centre of the glacier stream," he again says, "is urged onward by pressure from above, which is there resisted less than at the sides and bottom, owing to the comparative absence of friction. The lateral parts are dragged onwards by the motion of the centre, and move also, but it is quite compatible with this idea of semi-fluid motion that the bottom of the glacier should remain frozen to its bed, as some writers have supposed to be the case, though I am far from asserting this to be the fact, or even supposing it probable." . . . . . "The motion of a glacier resembles that of a viscid fluid, not being uniform in all parts of the transverse section, but the motion of the parts in contact with the walls being determined, mainly, by the motion of the centre." And he concludes this famous letter by urging that the admission of some fluid motion in a glacier seems to explain the chief facts of glacier movement:—(1) That it is more rapid at the centre than at the

sides, and (2) for the most part, most rapid near the lower extremity of glacier, but varying rather with the transverse section than the length. (3) That it is more rapid in summer than in winter, in hot than in cold weather, and especially more rapid after rain, and less rapid in sudden frosts. (4) It is farther in conformity with what we know of the plasticity of semi-fluids generally, especially near their point of fusion ..... such as sealing-wax, for example, exposed for a long time to a temperature far below their melting heat, and which have moulded themselves to the form of the surfaces on which they rest. (5) When the ice is very highly fissured, it yields sensibly to the pressure of the hand, having a slight determinate play, like some kinds of limestone, well known for this quality of flexibility. (6) Such a condition of semi-rigidity accounts for the remarkable veined structure which pervades it.

Meanwhile the observations of Forbes, and especially his claims to have discovered the veined structure of ice, were contested by Professor Agassiz, in a memoir published in the same magazine (Vol. XXXIII., 265, etc.); and thus began a scientific feud which was not only deplorable in itself, but eventually led to a very serious injury to science itself. I would here remark, that in this paper Agassiz reiterates his adhesion to the dilatation theory, and to the conclusion that glaciers do not move in winter, but only in summer.

Forbes continued to press his views as to the viscosity of glacier ice, and notably in his well known "Travels," published in 1843. In this work he writes, "*A glacier is an imperfect fluid, or a viscous body, which is urged down slopes on a certain inclination by the mutual pressure of its parts.*" He compares glacier ice to a moderately thick mortar or the contents of a tar barrel poured into a sloping channel. "Either of these substances," he says, "without actually assuming a level surface will *tend* to do so. They will descend with different degrees of velocity, depending on

the pressure to which they are respectively subjected. The friction occasioned by the nature of the channel or surface over which they move, and *the viscosity*, or mutual adhesiveness, of the particles of the semi-fluid, which prevents each from taking its own course, but subjects all to a mutual restraint..... The quantity of viscidity or imperfect mobility in the particles of fluids may have every conceivable variation ; the extremes are perfect fluidity on the one hand, and perfect rigidity on the other. A good example is seen in the process of consolidation of common plaster of Paris, which, from a consistency not thicker than that of milk, gradually assumes the solid state, through every possible intermediate graduation. Even water is not completely mobile ; it does not run through capillary tubes, and a certain inclination or fall is necessary to make it flow. Water will run freely on a slope of 6 inches in a mile, or a fall of one 10,000th part ; another fluid might require a fall of 1 in 1,000 ; whilst many bodies may be heaped up to an angle of several degrees before their parts begin to slide over one another.

"Thus a substance apparently solid may, under great pressure, begin to yield ; yet that yielding or sliding of the parts over one another may be quite imperceptible upon the small scale, or under any but enormous pressure. A column of the body itself is the source of the pressure of which we have now to speak.

"Even if the ice of glaciers were admitted to be of a nature perfectly inflexible so far as we can make any attempt to bend it by artificial force, it would not at all follow that such ice is rigid, when it is acted on by a column of its own material, several hundred feet in height. Pure fluid pressure, or what is commonly called hydrostatical pressure, depends not at all for its energy upon the *slope* of the fluid, but merely upon the *difference of level* of the two connected parts or ends of the mass under consideration.

If the body be only semi-fluid, this will no longer be the case; at least the pressure communicated from one portion (say of a sloping canal) to the other, will not be *the whole* pressure of a vertical column of the material, equal in height to the difference of level of the parts of the fluid considered; the consistency or mutual supports of the parts opposes a certain resistance to the pressure, and prevents its indefinite transmission. It must be recollected that in the case of glaciers, the pressing columns are enormous, the origin and termination of many of the largest having not less than 4,000 feet of difference of level; were they, therefore, perfectly fluid, or suddenly converted into water, the lower end would begin to move with the enormous velocity of 506 feet a second, or would move over 44 *millions of feet* in 24 hours. Now the velocity of the Mer de Glace is only about 2 feet in that time, a difference so enormous that the fluidity of a glacier compared to water will not appear so preposterous as it might at first sight do, considering the small degree of transmitted pressure required to be effectual.

"Again, it has been attempted to be shewn that a glacier is not coherent ice, but is a granular compound of ice and water, possessing under certain circumstances, especially when much saturated with moisture, a rude flexibility sensible even to the hand. Farther, it has been shown that the glacier *does* fall together and choke its own crevasses with its plastic substance."

Forbes then proceeds to argue that—

(1) From the proved result that the centre flows faster than the sides and bottom there follows a suggestive corollary. "I have no doubt," he says, "that glaciers slide over their beds, as well as that the particles of ice rub over one another, and change their mutual positions: but, I maintain that the former motion is caused by the latter, and that the motion impressed by gravity upon the superficial and central parts of a glacier (especially near its lower

end), pull the lateral and inferior parts along with them. One proof, if I mistake not, of such an action is, that a deep current of water will flow under a smaller declivity than a shallow one of the same fluid." And this consideration derives no slight confirmation in its application to glaciers, from a circumstance mentioned by M. Elie de Beaumont, which is so true, that one wonders it has not been insisted on, namely, that a glacier, where it descends into a valley, is like a body pulled asunder or stretched, and not like a body forced on by superior pressure alone.

(2) The comparatively slight difference between the motion of the centre and sides of a glacier is in accordance with the law prevailing with viscous bodies, that the retardation due to friction will be more completely distributed over the whole section in proportion as the matter is less yielding.

(3) The greatest variation of velocity in a glacier takes place, as it should in a viscous body, near the sides and bottom, while the higher and more central parts move most nearly together.

(4) Forbes confirmed, experimentally, in glaciers, Dubuat's law in regard to the flow of streams, namely, that their velocity at the top and bottom depends upon the actual velocity of the stream, and the amount of lateral retardation depends also upon the actual velocity of the stream.

(5) A glacier, like a stream, has its still pools and its rapids. When it is embayed by rocks it accumulates—*its declivity diminishes and its velocity at the same time*; when it passes down a steep, or issues by a narrow outlet, its velocity increases. The central velocities of the lower, middle, and higher regions of the Mer de Glace, are

1·398 ·574 ·925

and if we divide the length of the glacier into three parts, we shall find something like these numbers for its declivity,

15° 4½° 8°

Lastly, when the semi-fluid ice inclines to solidity, during

a frost, its motion is checked; if its fluidity is increased by a thaw, the motion is instantly accelerated. Its motion is greater in summer than in winter, because the fluidity is more complete at the former than at the latter time. The motion does not cease in winter, because the winter's cold penetrates the ice as it does the ground, only to a limited extent. It is greater in hot weather than in cold, because the sun's heat affords water to saturate the crevices: but the proportion of velocity does not follow the proportion of heat, because any cause, such as the melting of a coating of snow by a sudden thaw, as in the end of September, 1842, produces the same effect as great heat would do. Also, whatever cause accelerates the movement of the centre of the ice, increases the difference of central and lateral motion.

Meanwhile, Agassiz continued his researches, and in Desor's elaborate report of his experiments on the Aar Glacier, we find a reiteration of most of his views, and an elaborate defence of the infiltration theory, with many experiments cited to prove it. On one point he had to give way, however, and to confess that the experiment made by driving a series of six stakes in a line across the glacier as a test of its motion, shewed that the advance of the glacier caused them to arrange themselves in a curve whose convexity was inclined downwards. This, as M. Desor reports, far from confirming the opinion which M. Agassiz had previously hazarded, that the margins advance more rapidly than the middle, shewed that the centre advances more rapidly than the sides, almost to even double the extent, being in the ratio of 245 feet to 125 in one case and of 269 to 160 in the other (*Edin. Phil. Jour.*, XXXVI. 155, *Bibliotheque Universelle de Geneva*, 1843, Nos. 88 and 89).

He, however, still maintained, apparently, that the upper part of a glacier moves more slowly than the lower, and that in winter a glacier is virtually stationary (*id.*).

In the autumn of 1843, Forbes was again in Switzerland,

and, with the assistance of his guide, Auguste Balmat, satisfied himself, by marking rocks, etc., that glaciers move with considerable velocity even in winter (*E. P. J.*, XXXVI. 217, 218). A few months later, on visiting the South of Italy, he was able to compare the motion of glaciers with that of a lava stream. He pointed out that in two respects the comparison fails: (1) In respect of the great liquidity of the lava near its source; (2) From its unequal rate of consolidation a crust is soon formed more massive than the subjacent mass, and the fluidity is thus not distributed through the mass, "but a tolerably perfect fluid struggles with the increasing load of its ponderous crust, which it tears and rends by the mighty energy of hydrostatic pressure," and thus the crust gets broken, and the whole becomes more like a torrent loaded with blocks of ice than the regulated progress of a glacier, with a graduated retardation towards the sides. In other respects the analogy is more complete, as he shews in considerable detail. In all these comparisons we must remember that the analogy is not quite complete, or the results would probably be identical; but, as Forbes remarks, "ice passes from a brittle solid into limpid fluid by heat, while lava passes like sealing wax through every intermediate degree of viscidity."

In the experiments he made in 1844 on the Mer de Glace, which were conducted with great care and minutely measured, he showed by the convexity and regularity of the curves made by the moving points that the movement of the ice is molecular, and, as he says, "proving a regular plastic action of gravity or other propelling force, acting from point to point on the mass of the glacier" (*Phil. Trans.* 1845).

In July, 1844, Forbes applied his methods of observation, which had proved to him the molecular movement of the greater glaciers, to the smaller ones reposing in the cavities of high mountains or on the cols, which De

[illegible] [illegible] [illegible] [

with water, rendering the whole an imbibed mass, like a sponge, and consequently depends not only on the temperature of any period, but upon the wetness of the surface, whether derived from mild rain, thawing snow, or any meteorological accident (*id.*).

He thus sums up the various facts presented by crevasses in support of his plastic theory: "The general convexity of the crevasses upwards, notwithstanding the excess of motion in the centre; the general verticality of the crevasses, notwithstanding the retardation of the bottom; the perfect state of the crevasses every spring succeeding their visible collapse in autumn; the ascertained velocity of different parts of the glacier, and the diversity of the annual changes which their velocities present; the seemingly opposed facts showing the glacier to be subjected to powerful tension, producing crevasses, and yet to be under a compression which produces in some places the *frontal dip*; and finally, the renewal of the level of the ice during winter, which has been lost partly by superficial melting, but as much or more so by the attenuation and collapse of the glacier during summer" (*Phil. Trans.*, 1846).

The experiments of M. Agassiz's staff on the glacier of the Aar continued, and it was with some natural exultation that Forbes declared, as these experiments became more precise, so did their results accord more and more with his. *Inter alia*, they established, he says, that "the movement of the centre of that glacier was to that of a point five metres from the edge as 14 to 1. Such is the effect of plasticity. Thirteen-fourteenths of the motion of the glacier of the Aar are due to the sliding of the ice over its own surface, and one-fourteenth only to its motion over the soil" (*Ed. Phil. Jour.* XXXVIII.339). Shortly after the publication of these words M. Agassiz apparently abandoned the dilatation theory, of which he had been so long the champion. We find this change of view reported in the *Bibliothèque*

Universelle de Genève, for 1845, p. 347, as follows:—M. Agassiz considère le glacier comme formé d'un assemblage de fragments angulaires de glace, entre lesquels circule de l'eau dans laquelle on voit nager les animalcules vivants. Si l'on jette sur le glacier des liquides coloriés on les voit apparaitre à de grandes distance au fond des crevasses, mais ils ne peuvent pénétrer dans l'intérieur des fragments de glace. *La quantité d'eau qui gorge le glacier parait être la cause de son mouvement, en raison de la pression hydrostatique qu'elle exerce sur la masse.* En effet ce mouvement devient plus rapide lorsque l'eau abonde, et il se ralentit lorsqu'elle vient à diminuer par une cause quelconque; par exemple une chûte de neige pendant trois a quatre jours de gelée, ce qui oppose à ce que l'eau arrive à la surface du glacier: pendant ce temps il se vide d'eau comme une eponge pressée."

As Forbes says, this passage clearly shows that Agassiz had abandoned the dilatation theory, and accepted that according to which a glacier is a compound of ice and water moving under the impulsion of its own hydrostatic pressure, a view which Forbes himself had constantly pressed as explaining the cause of viscosity in glacier ice. As he says: "The hydrostatic pressure within the veins and crevices of the glacier itself can only produce motion by a plastic change in the figure of the mass, and the ductility of the glacier on the great scale becomes a corollary from the admission of internal pressure as a cause of motion" (*id.* XL.154—157).

Forbes, meanwhile, continued to press fresh experiments into his favour. M. Person is quoted by him as having shewn and published in the *Comptes-Rendus* for April 29th, 1850, that ice does not pass *abruptly* from the solid to the fluid state; that it begins to *soften* at a temperature of 2° centigrade below its thawing point; that consequently between 28·4 and 32° of Fahrenheit, it is actually passing through

various degrees of plasticity within narrower limits, in the same manner that wax, for example, softens before it melts. M. Person deduces this from the examination of the heat requisite to liquefy ice at different temperatures. The following sentences contain his conclusions in his own words: "Il parait d'apres mes experiences que le ramollissement qui précède la fusion, est circonscrit dans une intervalle d'environ 2 degrés. La glace est donc un des corps dont la fusion est la plus nette; mais cépendant le passage de l'état solide à l'état liquide s'y fait encore par degrès, et non par un saut brusque." Forbes adds, that from his own experiments and those of Agassiz, it is clear that the normal temperature of the great mass of a glacier is between 28° and 32° Fahrenheit, that the coldest nights only affect the temperature of its superficial layers, that the lower parts which are habitually saturated with water in summer are seldom reduced below the freezing point, even by the prolonged cold of winter, since it is then covered with snow which has the property of preventing any profound congelation in common earth; and as ice is probably a better conductor of heat than the ground, it is incredible that a thickness of many hundred feet of ice, saturated with fluid water, should be reduced much below the freezing point, or should even be frozen throughout. The fact that water continually flows from under glaciers in winter shews that they are not so frozen. While the fact that, even in February, the source of the Arveiron becomes whitish and dirty as in summer before a change of weather, proves that in the middle of winter a temporary rise of temperature over the higher glacier regions, not only produces a thaw there, but finds the usual channels still open for transmitting the accumulated snow-water. It thus appears quite certain that ice, under the circumstances in which we find it in the great bulk of glaciers, is in a state more or less *softened* even in winter; and

that during nearly the whole summer, while surrounded by air above 32°, and itself at that temperature, it has acquired a still greater degree of plasticity, due to the latent heat which it has then absorbed (Forbes "Sixteenth Letter on Glaciers," *Ed. New Phil. Jour.*, Jan., 1851).

His opponents continued, however, to appeal to the experience of hand specimens of ice, which are so brittle, and whose behaviour seems so remote from that of plastic bodies. In answer to them he writes:

"I certainly never expected, when promulgating the viscous theory, that it would have met with so much opposition on the ground that the more familiar properties of ice are opposed to the admission of its plasticity: and that the fragility of hand specimens should be considered as conclusive against the plastic effect of most intense forces acting on the most stupendous scale upon a body placed in circumstances which subject it to a trial, beneath which the most massive constructions of the pyramid building ages would sway, totter, and crumble. . . . in these days when the barriers of the categories are so completely beaten down, I had not expected to meet with so determined an opposition to the proposition that the stupendous aggregation of freezing water and thawing ice called a glacier, subjected to the pressure of thousands of vertical feet of its own substance might not under these circumstances possess a degree of yielding, moulding, self-adapting power, sufficient to admit of slight changes of figure in long periods of time. Still less could I have anticipated that when the plastic changes of form had been measured, and compared and calculated and mapped, and confirmed by independent observers, that we should still have had men of science appealing to the fragility of an icicle as an unanswerable argument. More philosophical, surely, was the appeal of the Bishop of Annecy from what we already know to what we may one day learn if willing to be taught.

Quand on agit sur un morceau de glace, qu'on le frappé, on lui trouve une regidité qui est en opposition directe avec les apparences dout nous venons de parler. *Peut-être que les expériences faites sur de plus grandes masses donneraient d'autres résultats*" (*Phil. Trans.*, 1846).

In 1855, when Forbes wrote the article on glaciers in the *Enc. Britt.*, he spoke in very emphatic terms about his theory, which he said was then very generally accepted. In answer to the obvious fact that ice is superficially a brittle solid, and does not seem readily plastic, he urged that sealing wax, pitch, and other similar bodies adapt themselves *with time* to the surfaces on which they lie even at atmospheric temperatures, while they maintain at the same time the quality of excessive brittleness under a blow or a rapid change of form. He went on to press that ice does not pass at once and *per saltum* from the solid to the liquid state, but absorbs its latent heat throughout a small range of temperature (between 28°·4 and 32° of Fahrenheit) which is precisely that to which the ice of glaciers is actually exposed; that a glacier is not a crystalline solid like ice tranquilly frozen in a mould, but possesses a peculiarly formed and laminated structure, through which water enters (at least for a great part of the year) into its intrinsic composition. Putting together these facts, and admitting the differential motion of the parts, which no one now contests, the quasi fluid or viscous motion of the ice of glaciers is not a theory but a *fact*; a substance which is seen to pour itself out of a large basin through a narrow outlet, without losing its continuity, the different parts of which, from top to bottom, and from side to centre, possess distinct though related velocities, which moves over slopes inconsistent with the friction between its surface and the ground on which it rests—which surmounts obstacles, and even if cleft into two streams by a projecting rock, instead of being thereby anchored as a solid would necessarily be, re-unites its streams

below, and retains no trace of the fissure, leaving the rock an islet in the icy flood; a substance which moves in such a fashion cannot in any true sense of the word be termed a rigid solid, and must be granted to be ductile, viscous, plastic, or semi-fluid, or to possess qualities represented by any of these terms which we may choose to adopt as least shocking to our ordinary conception of the brittleness of ice," and it was no doubt with some satisfaction that Forbes quoted the words of Mousson in his *Die Gletscher der Jetztzeit*, p. 162, speaking of the plastic theory "Er steht noch heute unangefochten da," and that he numbered among his warmest supporters Darwin and Whewell.

While it was generally admitted that the phenomena accompanying the motion of glaciers had been shown by Forbes to exactly reproduce the conduct of a plastic body which can mould itself to its boundaries when in motion, and which has a continuous differential motion, the conduct of hand specimens continued to be a stumbling block. As Tyndall urged, a slight blow, if properly directed, will split open a block of ice 10 or 15 cubic feet in volume, and as Mr. McGee says, "on a cold, still night the steel runner of a boy's skate initiates a fracture miles in length in the ice bridging a river, which shews that if ice is plastic that it is also very rigid under some conditions," but the fact which weighed most with observers was the experimental test applied by Professor Moseley, of Cambridge. These experiments were described in a paper read before the Royal Society in 1869, in which he published some very interesting results on the shearing force of ice, in which, according to one experiment, the shear per square inch, or unit of shear, was 72·433lb., and in another case 76·619lb., the mean being about 75lb., while, according to his calculations for a glacier to move by its own weight, as Tyndall had seen it move in the Mer de Glace, the unit of shear should not have been more than 1·3193lb., whence he concluded that the weight of a glacier alone is insuffi-

cient to account for its descent" (*Phil. Mag.*, XXXVII. 233-235). These experiments had a very great effect on the scientific mind of Europe. They seemed conclusive against Forbes's views. As Mr. Trotter says, "granting that the shearing strength of ice as deduced from his (Moseley's) experiments represents even approximately the resistance to shearing under the actual circumstances of glacier motion, his objection to Forbes's view is fatal."

Mr. Moseley did not fail to use the weapon he had discovered, and pressed with great persistency the view that his experiments had proved the viscous theory to be untenable. On Mr. Moseley's death, Mr. W. R. Brown, who championed his views, (*Proceedings of the Royal Society*, vol. XXXIV.) adduced fresh arguments against Forbes, from more general considerations. He urged that the existence of ice cliffs, such as those in the crevasses in South America, 300 feet thick, which ought to flow over if Forbes's view be right, seem to militate against it. Putting aside Forbes's own experiments about crevasses themselves being short-lived, the argument of Mr. Brown had been already answered by anticipation by Dr. Whewell. He says: "Soft pitch will stand on cliffs some inches high, soft clay will stand on cliffs many feet high; clay may stand on cliffs hundreds of feet high, and yet be plastic, if the mass be very large, and the pressure distributed through it be powerful enough to make one part move past another. We cannot doubt that clay might be hard enough to stand on such cliffs, and yet soft enough to slide down a sloping valley as a plastic substance, if the valley were filled with it for many miles long and hundreds of feet thick; and still more if there were streams of water running through all parts of the mass" (*Phil. Mag.*, XXVI. 172 and 3).

Again, as Mr. Trotter says, "the spreading out of a glacier like the Rhone glacier when it emerges from a gorge on to a comparatively open space, is in itself a convincing

proof that ice at 0° C. will not stand permanently on a vertical cliff of any considerable height. It gives way gradually, but still it gives way" (*Proc. Roy. Soc.*, XXXVIII. 103).

These were, however, subsidiary issues. The main one converged upon Mr. Moseley's famous experiments, and no wonder that they led to a wide revolt against the plastic theory, and that a great impetus was given to various transcendental views, such as those of Thomson and Croll, already described, and when these were answered led to another suggestion, namely that of Tyndall.

Tyndall's most important pronouncement in criticism of Forbes's views is contained in the following sentence, published as an *obiter dictum*. "The very essence of viscosity," he says, "is the ability to yield to a power of *tension*, the texture of the substance, after yielding, being in a state of equilibrium, so that it has no strain to recover from." . . . He then goes on to urge that ice will not stretch like well-known plastic bodies, and while it yields to pressure it does not do so to tension (*Proc., Roy. Inst.*, 1858, 551—553). "Viscosity," he says elsewhere, "consists in the power of being drawn out when subjected to a force of tension, the substance, after stretching, being in a state of molecular equilibrium, or in other words, devoid of that elasticity which would restore it to its original form" (*Glaciers of the Alps*, 312). He then goes on to urge that on dislocated slopes, where tar or treacle would flow without breaking across, ice breaks, and he cites certain cases in the Alps. He similarly refers to crevasses as breaks inconsistent with a viscous character, since the maximum strain upon the ice is comparatively so small; and he further adds, that no single experiment on great masses or small shows that ice possesses in any sensible degree that power of being drawn out which seems the very essence of viscosity. Professor Tyndall carefully guards himself, however, against being supposed to believe that a glacier

acts otherwise than conformably to the law of semi-fluid motion; all he denies is that ice is of a gluey tenacity, and will stretch like a plastic substance.

We will now turn to Tyndall's own theory. This theory, which he applied to the motion of glaciers, was based upon a fact first published by Faraday in a lecture at the Royal Institution as early as 1855, according to which "when two pieces of ice with moistened surfaces are brought into contact they become cemented together by the freezing of the film of water between them, while, when the ice is below 32° Fahr., and therefore dry, no effect of the kind can be produced" (See *Glaciers of the Alps*, 357).

"A generalization from this interesting fact," says Tyndall, "led me to conclude that a bruised mass of ice, if closely confined, must recement itself when its particles are brought into contact by pressure" (*id.*). He therefore appeals to certain experiments which had, in fact, been made in a different way by others.

In a letter addressed to Forbes, on April 4th, 1846, by Mr. Christie, Secretary of the Royal Society, that gentleman instanced the experiment of filling a hollow iron shell with water, and exposing it to frost with the fuze hole uppermost, when the water will freeze, and protrude a cylinder of ice from the fuze hole, and as the experiment is continued the fuze continues to grow, in proportion as the water freezes. "No thawing takes place in the process. Does not this show plasticity even in very small masses of ice?" says Mr. Christie. The experiment was repeated by Forbes in glass vessels which could be closely watched. He first put a ring of a greasy matter of a red colour round the inside of the vessel, keeping the aperture clean. When the ice protruded it was found incased with red, in some cases in the form of a red ring, which, as he says, could not have been unless the plastic substance of the ice had been forced laterally, and, by a converging pressure from all sides, up

even to the particles in contact with the interior of the glass, so as to be forced through the contracted outlet as a tenacious fluid under its own pressure, or a plastic solid subjected to a considerable force would do under like circumstances. The success of these experiments Forbes attributes to the slowness of the process of congelation employed, which lasted several hours, or, in Mr. Christie's case, several days, and which therefore affords analogies with the gradual internal movements of a glacier (*The Theory of Glaciers*, 161 and 168).

To turn to Tyndall's experiments, he tells us how in the course of them, moulds of various forms were hollowed out in boxwood, and pieces of ice were placed in them and subjected to pressure. In this way spheres of ice were flattened into cakes, and cakes formed into transparent lenses. A straight bar of ice, six inches long, was passed through a series of moulds augmenting in curvature, and was finally bent into a semi-ring. A small block of ice was placed in a hemispherical cavity, and was pressed upon by a hemispherical protuberance, not large enough to fill the cavity; the ice yielded, and filled the space between both, thus forming itself into a transparent cup. In short, he says, every observation made upon glaciers and adduced by writers on the subject in proof of the viscosity of ice was shown to be capable of perfect imitation with hand specimens of the substance (*Glaciers of the Alps*, 321). So far there was nothing on the surface to traverse Forbes's views in regard to ice being viscous, but the contrary, as Tyndall himself says. "The experiments prove to all appearances that the substance is even much more plastic than it was ever imagined to be by the founders of the viscous theory" (*id.*); but in the case of these experiments the inference would not have been quite correct. The process by which the ice was moulded into shape in them did not involve a continuous flow of semi-

fluid particles over each other, thus adapting the ice to its new shape, but the crushing by force of the ice into an incoherent state, and then the process of refreezing it into a solid mass.

Tyndall himself describes it as a process of bruising and regelation, and denies that ice is viscous at all. On the contrary, he says emphatically, that a mass of ice at 32° is very easily crushed, but it has as sharp and definite a fracture as a mass of glass (*id.* 551).

I am bound to say that I can find nothing in the machinery by which glaciers are formed at all analogous to these experiments, except the initiatory stage, when damp snow is converted into continuous *névé* by pressure. From that point down to the foot of the glacier I can find evidence only of the ice being more and more condensed as the pressure is exerted upon it by its walls, until it acquires the character of blue ice. I can nowhere trace evidence of the pressure being sufficiently great, and such as to crush the ice into powder, or to assimilate it in any way to the disintegrated condition which ice assumes in a Bramah press. When the pressure is the greatest, and the blue veins are produced, that is, when the great mass of the ice is detained by some projecting obstacle, there we have the least sign of disintegrated ice. On the contrary, there the ice is most transparent, and where the ice is embayed, and has therefore to spread itself and accommodate itself the most, then the signs of internal strain in the form of blue bands are conspicuously absent.

Similarly, if we examine the ice at the base of a glacier by entering one of the well-known ice caves, instead of finding its internal structure filled with cloudy lines, and more or less opaque, as Tyndall himself shewed to be the case when incipient crushing is in progress (*Glaciers of the Alps*, 409 and 10), we find the ice to be most blue and most transparent. On this matter Professor Bonney writes:

"On entering ice caves, etc., underneath glaciers, where ice fills up cavities, the ice appears to enter these cavities not by fracture and regelation, but by change of form, as in the case of a plastic body, for it is remarkably clear and solid looking" (*Jour. Geol. Soc.*, XIII. 199).

Professor Tyndall himself allows that, according to his own view, "it is manifest that the continuity of the fractured surfaces cannot be completely and immediately reclosed after rupture. It is not the *same* surfaces that are regelated, and hence the coincidence of the surfaces cannot be perfect. They will enclose for a time capillary fissures" (*Proceedings Royal Inst.*, 1857, p. 322 note), but the existence of such capillary fissures in the deep ice is absolutely denied by Professor Huxley, who accompanied Professor Tyndall to Switzerland.

Professor Huxley's words are: "All deep ice, that is, all ice situated more than a few inches below the surface, is as solid as glass or marble and as devoid of any but accidental fissures. The glacier, however, where exposed to the atmosphere, presents what may be called 'a superficial layer' of very different character. It is composed of larger or smaller granules of exceedingly irregular form, separated by very obvious fissures, but nevertheless so fitted into one another as to cohese with firmness. The thickness of the superficial layer varies a good deal, seven or eight inches being rather above the average depth. Wherever you clear away this superficial layer you find beneath it what I have termed deep ice, that is, ice in which neither fissures nor granules are visible." Professor Huxley did not content himself with a microscopic examination of glacier ice, but he tested its porosity by making cavities, some of them with very thin walls, and filling them with coloured liquids, and thus testing its permeability; and he says, "I can only conclude from these experiments that the chief substance of a glacier is as essentially impermeable as a mass of marble or slate; and that, though it may be

traversed here and there by fissures and cracks, these no more justify us in speaking of glacier ice as porous than the joints and fissures in a slate quarry give us a right to term slate porous. We do not call iron porous because water runs out of a cracked kettle" (*Phil. Mag.* 4th ser. XIV. 250).

This conclusion of Professor Huxley seems absolutely fatal to Professor Tyndall. As Dr. J. Ball says, "If we are to adopt his conclusion, then we must cease to believe with Professor Tyndall, that glacier ice is enabled to advance in conformity with the law of viscous motion, by fracture and regelation" (*Phil. Mag.*, 4th ser., XIV. 502).

When we turn from these to another series of facts, whose lesson is ignored by Professor Tyndall, namely, the proved differential motion by which every point from the centre of a glacier to the side, from its summit to its base has a different motion, we have a condition which seems to me compatible only with semi-fluid motion, and utterly unexplainable by any theory of crushing and regelation.

Referring to Moseley's argument on the shearing force of ice, Mr. Trotter says:—"It seems to be decisive against the belief that the ordinary comparatively undisturbed motion of a glacier along a moderately sloping bed takes place by fracture and regelation. Moseley's value of the shearing strength of ice, which has been shown to be enormously too great as a measure of the resistance of ice to slow shearing, would appear on the other hand to be an inferior limit to the resistance to the shearing fracture which must precede regelation" (*Proc. Roy. Soc.*, XXXVIII. 108).

Again, Professor Tyndall refers to experiments of his own upon the Mer de Glace, showing its motion in winter when the estimated temperature was 5 degrees below zero centigrade. How, at such temperatures, can regelation occur at all? The ice surfaces would be all dry and incapable of freezing together. We must remember that it is only damp surfaces that will freeze together again. Professor

Tyndall acknowledges that below 32° ice does not possess the property of regelation, and it has been proved that a glacier is always moving in all its parts in winter as well as in summer, below as well as above. It means that the interior of a glacier must, in order to justify Professor Tyndall's theory, be above the freeing point or at the freezing point in winter, which is completely contrary to the facts as we know them, in the glaciers of Greenland and high latitudes, which have been shewn to have a considerable winter motion.

These considerations seem fatal to Professor Tyndall's theory, and its breakdown made men revert again to Forbes's views, notwithstanding the apparently insuperable objection contained in Moseley's experiments. Among these champions of the Scotch philosopher was Dr. M. Williams. "We have direct evidence that ice of great thickness," he says, "actual glaciers, may bend to a considerable curvature before breaking. This is seen very strikingly when the uncrevassed ice-sheet of a slightly inclined *névé* suddenly reaches a precipice and is thrust over it. If Mr. Geikie were right (*i.e.*, if ice were a rigid and not a plastic body) the projecting cornices thus formed should stand straight out, and then when the transverse strain due to the weight of this rigid overhang exceeded the resistance of tenacity, it should break off short, exposing a face at right angles to the general surface of the supported body of ice. . . . . Some very fine examples of such ice cornices are visible from the ridge separating the Handspikjen Fjelde from the head of the Jostedal, where a fine view of the great *névé* or sneefornd is obtained. This side of the *névé* terminates in precipitous rock walls; at the foot of one of these is a dreary lake, the Styggewand. The overflow of the *névé* here forms great bending sheets that reach a short way down, and then break off and drop as small icebergs into the lake." (*Quart. Journ. of Science*, VII. 220—221).

The position in which the problem now stood was remarkable. It was admitted by everybody that the general phenomena of the motion of a glacier exactly reproduces that of a viscous body moving through a channel under the influence of its own weight, and that Forbes's view seemed incontrovertible, and every attempt to explain the motion of glaciers by other processes had failed. But for the experiments of Moseley, which went to shew that the shearing resistance of ice is not sufficiently low to allow us to treat a glacier as a viscous mass, and that consequently gravity is not strong enough to do the work demanded from it, there would have been no hesitation among scientific men in accepting the plastic theory as alone valid.

It had not occurred to enquirers to call in question Moseley's experiments. This was now to be done, with the result of completely vindicating Forbes's view.

Mr. Ball objected, on theoretical grounds, to experiments like Mr. Moseley's upon artificially formed ice being applied to ice of another kind altogether, namely, glacier-ice, a conclusion for which, as we shall see, he had full warrant. He also urged that while the shearing in a glacier, whatever its amount, takes place very slowly, in Mr. Moseley's experiment it was very fast. Moseley's own experiments show, that if we want to shear ice quickly, a weight of 120 lbs. is required, while, if the thing is done more slowly, 75 lbs. will suffice, and this gives point to Mr. Ball's criticism, that to ascertain the resistance opposed to very slow changes in the relative position of the particles, so slight as to be insensible at short distances, Mr. Moseley measures the resistance opposed to rapid disruption between contiguous portions of the same substance (*Phil. Mag.*, XL. 158).

Mr. Matthews and Mr. Reilly, by careful experiments, emphasized this argument of Mr. Ball, and showed how important an element time is in the shearing of ice; the actual differential motion of a glacier ranging for molecules

the tenth of an inch apart, and at an interval of 24 hours, from the $\frac{1}{2150}$ to the $\frac{1}{10000}$ of an inch, while Mr. Moseley inferred the shearing force in ice to be 75 lbs., from experiments in which he caused a solid cylinder of ice to shear an inch in half an hour (*Phil. Mag.*, XLII. 420).

It was in 1870 that Mr. Matthews tried his famous experiment upon the shearing of ice, which gave an entirely different result to that of Mr. Moseley. A plank of ice, 6 inches wide 2⅜ inches thick, was sawn from the frozen surface of a pond, and supported at each end by bearers 6 feet apart. The whole weight of the plank could not have exceeded 37½ lbs, and its cross-section was nowhere less than 14 inches. From the moment the plank was placed in position it began to sink, and continued to do so until it touched the surface over which it was supported. At the point of contact it appeared bent at a sharp angle, and was perfectly rigid in its altered form. The total deflection was 7 inches, which had been effected in about as many hours, under the influence of a thaw, during which the plank diminished very slightly in thickness. It was thus shewn that ice can change its form under strains produced by its own gravitation (*Alpine Journal*, 1870, 426).

The meaning of this experiment was very plain. Mr. Moseley himself says of this bending, "when the ice takes a distinct set, every particle, except those at the points of support, is made to move in the direction in which the plate is bent, those particles which are at the point of greatest inflation being made to move furthest, and those nearer to it being always made to move further than those most remote, so that every particle moves over that which is alongside towards the nearest point of support; and being assumed to have taken a set, it must have sheared over it." That is to say, the motion of the plank is precisely such a motion as Forbes's theory requires. Mr. Matthews pertinently asks:—If the shearing force of ice be 75lbs. as

Mr. Moseley requires, and the cross section of the ice plank is 14 inches, it must require a pressure of 1,050lbs. in order to shear it. How then does it come about that it shears under a pressure of 37½lbs? The experiments shewed that, even if the whole weight of the plank were at work in shearing it only along the supporting edges, instead of a portion of it being taken off by the bearers and being otherwise extended, it could not exceed 37½lbs. for the whole area, which, for the two surfaces, would be $\frac{37\frac{1}{2}}{28}$, or about 1⅓lbs. to the square inch (*Phil. Mag.*, XLII. 333—4).

In March, 1871, Professor Bianconi published a paper in the *Memoirs of the Bologna Academy*, ser. III., vol. I. p. 156, entitled, "Esperiénze intorno alla flessibilità del Ghiaccio." In this paper he refers to experiments which he tried from 1866 onwards upon beams of ordinary ice suspended on points and weighted in between. In these experiments he found that the beam acquired a curved flexure, and when it was reversed, and the weight again attached, it curved in the opposite direction. In another set of experiments he showed that after some hours a beam of ice is susceptible of torsion. In other experiments which he tried with granular ice, formed from snow, the results were more marked. To his memoir are attached plates in which the amount of bending and torsion are shown. The general result is summed up in the following words: Conchiudo, il ghiaccio possiede una flessibilita, o pieghevolézza assai lente, ma bene spiegata, alla temperatura di +2, +3 etc. mentre rimane in ogni momento presente la somma ma fragilita (*op. cit.* 165).

In the 4th volume of *Nature* Professor Tyndall published some experiments he himself made on ice from the Morteratsch Glacier in 1871. In these experiments it was clearly shown that a stout rectangle of clear and continuous ice cut from the glacier, when properly supported and weighted, showed signs of bending after twelve hours. Similar

experiments were made upon bars of ice from the harder and firmer ice of the sand cones. When not too large these showed similar signs of bending very quickly, and the flexure in each case was *permanent* and not due to elasticity (*Nature*, vol. IV. 447).

More remarkable were the experiments of Mr. John Aitken, described in the 7th volume of the same periodical (287—288), from which he deduced the conclusion that the plasticity of ice depends largely on the amount of air it contains. Having dissolved a large quantity of air in water, he filled some tubes with it. When frozen he withdrew the ice in the form of rods, which he then placed on supports eight and a half inches apart, and hung a pound weight in between. The beam, he says, at once began bending, and continued bending so long as the weights were left on them, thus proving the viscosity of the ice. In further experiments with rods made from compressed snow, afterwards frozen in a freezing mixture, and therefore more like glacier ice, the results were even more marked, one of the beams bending an inch in five minutes. Eventually Mr. Aitken succeeded in twisting such ice rods round cylinders, and thus forming solid ice rings from straight beams of ice.

In 1877, Professor Pfaff published the results of some careful experiments, which went to show that even the slightest pressure when applied continuously, and when the temperature of the ice is near the melting point, is sufficient to displace the particles of ice. "It follows," he says, "that ice near its melting point behaves *indeed like wax*." Again he says, "It is still constantly assumed, on the ground of some of Tyndall's experiments, that ice is destitute of *extensibility* and *flexibility*, although repeated observations recently made compel us to ascribe to ice some flexibility. The oldest observation of this kind known to us originated with Kane, who remarked that a large lump of ice with its edges resting on two others became curved in the

course of some months." Professor Pfaff then details some experiments confirming this one, and like others I have already quoted. "I next endeavoured," he says, "to determine the amount of extension of ice by *traction*, and he attached a weight to a prism of ice. After seven days, signs of stretching were clearly visible. It is therefore shown," he says, "that a pull continued for a long time, even when it is slight, stretches ice, that near its melting point it shews itself like other bodies yielding to pressure as well as to pull, and at a temperature in the vicinity of zero, it is to be regarded as an eminently plastic substance" (*Phil. Mag.*, I. 333—336).

In 1883, Mr. C. Trotter tried some experiments on the shearing of ice in an ice grotto at Grindelwald, the apparatus being placed about 18 metres from the edge of the glacier, 25 or 30 metres below its upper surface, and about the same above its bed, so as to have conditions of temperature like those of an actual glacier, and the ice used was cut from the glacier itself. The result was to show that under a shearing force rather more than double that which, according to Canon Moseley's calculations, is exerted by gravity in the Mer de Glace, near the Tacul, but $\frac{1}{3}$th only of his smallest value of the shearing force of ice, the amount of shear was actually larger than that implied in any of the ordinary cases of glacier motion, and he concludes that there is little doubt that under conditions closely resembling those of the interior of a glacier, and under the influence of forces comparable with those of gravity, hand specimens of ice shear in the same manner as a truly viscous solid would (*Pro. Roy. Soc.* XXXVIII. 100—101).

The observations of Tyndall upon crevasses do not prove that ice is not extensible, but that it is incapable of any appreciable elastic extension before it gives.

"I believe, therefore," says Mr. Trotter, "that the weight of

evidence tends to shew that ice at or about 0° C. is just as truly viscous as pitch or sealing wax at temperatures at which they are brittle, but yet capable of yielding to the continuous application of a very moderate force. The viscosity of ice however, probably diminishes very rapidly with the temperature. . . . . This is in complete accordance with the facts of the changes which take place in a glacier during the winter. The terminal melting ceases, but the advance of the end of the glacier into the valley is very slow, and probably ceases altogether in the depth of winter. Higher up, the forward movement of the surface continues, though at a slower rate than in summer, and though the glacier does not lengthen much in winter, it thickens considerably, and the surface rises, often through many feet, so as to make up the enormous waste of the summer."

In May, 1887, Dr. Mann read an important paper before the Royal Society upon some experiments he performed in the Engadine upon the shearing of ice. In these experiments, as he tells us, in order to eliminate the influence of regelation, the experiments were carried on at low temperatures, the *highest* being −2·6 C., number 2 −1·0° C., and number 3 −0·5° C. The ice was frozen in a cylindrical mould, and in order to exclude air the water was boiled. Without giving the details the result obtained by Dr. Bain was that "ice subjected to tension stretches continuously by amounts which evidently depend on the temperature and on the tension stress. When the stress is great, and the temperature not very low, it amounted to as much as 1 per cent of the whole length per day. When the temperature is lower and the stress is less, the extension is less, but still such as can be measured. So continuous and definite is the extension that it can even be measured from hour to hour. . . . . Hence differential motions resulted in the ice. These motions and extensions took place at temperatures which preclude

all possibility of melting and regelation. . . . . That there is such extension, and that it goes on continuously with all stresses above 1 kilo. per square centimetre and at all temperatures between −6° C. and freezing point, is shewn by the above experiments. . . . In the discussion, for the most part *a priori*, on the extensibility of ice, sufficient importance has not usually been assigned to the necessity of distinguishing between the effect of even a small blow or jar, and that of a much greater force applied gradually and steadily during a long interval. A bar of ice may bear a stress of 4 and 5 kilos per square centimetre if the load is steady, which would fracture at once with a much smaller sudden stress, especially if not uniformly distributed" (*Pro. Roy. Soc.*, XLII. 491-501).

In the following year similar experiments were repeated by Messrs. Mc.Connell and Kidd, "who established," to use their own words, "that not merely the rate, but even the very existence, of the extension, depends on the structure of the ice." They shewed that when the ice consists of a single crystal, no extension takes place, thus, *pro tanto*, explaining the results of some of the earlier experiments. Thus clear ice cut from the surface of a bath, which proved to be a rough regular crystal, shewed hardly any extension; ice of irregular structure made in a mould, shewed considerably more. This made it obvious, that for the purpose of testing the question as applied to the motion of glaciers, actual glacier ice must be used. "And the experiment was next tried upon actual glacier ice, taken from the natural caves at the foot of the Morteratsch Glacier." To use the actual words of the experimenters:—

"We tested three pieces, which were quite sufficient to disprove the common notions, that glacier ice is only plastic under pressure not under tension, and that regelation is an essential part of the process. They showed at the same time the extreme variability of the phenomenon. The first extended

at a rate of from 0.013 mm. to 0·022 mm. per hour per length of 10 cm., the variation in speed being attributable to the temperature. The second piece began at a rate of 0·016 mm. and gradually slowed down till it reached, at the same temperature, a rate 0·0029 mm., at which point it remained tolerably constant, except for temperature variations, till a greater tension was applied. The third piece, on the contrary, began at the rate of 0·012 mm., increased its speed with greater tension to 0·026 mm., and stretched faster and faster with unaltered tension till it reached the extraordinary speed of 1·88 per hour per length of 10 cm. We put on a check by reducing the tension slightly, whereupon the speed fell at once to 0·35 mm., and gradually declined to 0·043 mm. . . . During twelve hours, with a maximum temperature $-9°$ and a mean temperature probably $-10·5$, the rate under the light tension of 1·45 kilo. per sq. cm. was 0·0065 mm." . . . . "We tried further experiments on compression of ice, the pressure being applied to three nearly cubical pieces at once. Of three pieces of glacier ice, under a pressure of 3·2 kilos per sq. cm., the mean rates of contraction during five days were respectively 0·035 mm., 0·056 mm., and 0·007 mm. per hour, per length of 10 cm. These figures show that while the plasticity varies enormously in different specimens, the rate of distortion is of the same order of magnitude, whether the force applied be a pull or a thrust. . . . . We have now shewn by direct experiment that ordinary ice, consisting of an irregular aggregation of crystals, exhibits plasticity both under pressure and under tension, at temperatures far below the freezing point—in the case of tension at any rate down to $-9°$ at least, and probably much lower. . . . . It will be interesting to make some comparison between the figures we have given and the plasticity actually observed in the motion of glaciers. Perhaps the most striking proof of the existence of plasticity

is the great increase of velocity from the side to the centre of a glacier. The most rapid increase mentioned by Heim (*Gletscherkunde*, 147) among the glaciers of the Alps is on the Rhone glacier on a line 2,300 metres above the top of the ice fall. At 100 metres from the Western bank, the mean yearly motion, 1874 to 1880, was 12·9 metres; at 160 metres from the bank it was 43·25 metres. This gives an increase of velocity in each metre across the glacier of 0·00058 metres per hour." Having calculated out what this means, our authors proceed: "Thus the maximum rate of extension in the case we have taken on the Rhone glacier is 0·0029 mm. per hour per length of 10 cm. This, be it remembered, is the most rapid extension selected from a large number of measurements on different glaciers and at different times, and yet only one of the three specimens of glacier ice showed a rate less than this, and that was under one-third of the breaking tension. The larger the specimen the greater average plasticity would it display."

In some still more recent papers read before the Royal Society by Mr. Thomas Andrews, he shows experimentally that the shearing force of ice is largely dependent on its temperature. "In the majority of instances," he says, "it was found that if the plasticity of the ice at −35 F. be called 1 at 0° F. it would be about twice as much, and at 28 F. the plasticity would be about four times as great as at 0° F., or eight times as much as at −35 F. . . . . This is in accord with the practical cessation of motion in glaciers during the cold of winter. It was also noticed that the plasticity of the naturally frozen pond ice was manifestly greater than that of the prepared pure ice."

These experiments have shewn conclusively that Mr. Moseley's tests which misled so many scientific men were based on a mistake, and with the disappearance of Moseley's experiment, disappears the only evidence that has been forthcoming against the splendid induction of Forbes.

We may take it, therefore, as clearly proved, that glacier-ice is not a rigid body, but a plastic one; and that its movements may be compared with those of pitch or other plastic substances, whose several parts can roll over one another. When ice moves under the influence of gravity, except on very rapid slopes, it acts like other plastic substances act. Its lower surface, in contact with the ground, is dragged by friction, and moves very little, while its upper part flows faster. If we pour pitch on a table, we find that it spreads out, not by the bottom of the mass spreading, but by the edges rolling over; the upper stratum curling round to form the lower one, which is dragged by the surface of the table. Just as a drop of water rolls down a plain, leaving in its track the successive bottom layers of itself.

In claiming ice as a plastic substance I do not mean that it is completely plastic, but that it behaves like sealing wax and other similar bodies, which mould themselves with time to the surfaces on which they lie, even at moderate atmospheric pressures, and maintain, meantime, the quality of excessive brittleness under a blow or rapid change of form. The very fact of its cracking and forming crevasses shows that it is not perfectly plastic, but under certain conditions of tension will snap like a brittle substance. Its viscosity doubtless also varies both with its temperature, as Forbes urged, and also with the character of its molecular structure; and we may conclude as the result of our inquiry, that the motion of a glacier is due in the main to the actual flow of its substance, which goes on continuously, and, secondly, to a certain sliding over its bed, and certain more sudden movements due to large masses cracking asunder under great tension, the first being no doubt much the most potent and influential of these causes. So far as we can judge, none of its motion is due to molecular movements other than those induced by gravity,

If ice were contained in a basin, like water in a lake, or spread out on a level plain, it would neither crack nor move unless thrust out by external pressure, and such pressure in nature can, so far as we see, only be derived from gravitation.

As Mr. Trotter puts it: "The fuller consideration of the physical properties of glacier ice leads to essentially the same conclusions as those to which Forbes was led 41 years ago, by the study of the larger phenomena of glacier motion, that is, that the motion is that of a slightly viscous mass, partly sliding upon its bed, partly shearing upon itself under the influence of gravity" (*Proc. Roy. Soc.*, XXXVIII. 107).

This conclusion is a very important one. It displaces a great deal of ingenious and in some cases transcendental reasoning on the nature and phases of ice, with which the writings of very distinguished men have been sophisticated in the last quarter of a century; and it effectually disposes of the theories of great ice sheets which the current school of glacial geologists has imposed on the credulity of men of science.

On the Intensity of Transmitted Light when the coefficient of transmission of the medium is a function of time. By James Bottomley, B.A., D.Sc., F.C.S.

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In this investigation I suppose that we have a cylinder containing in solution some colouring matter which is undergoing chemical change, and that in consequence its absorptive power varies. Let the side of the cylinder be opaque so that light is admitted by the base and is transmitted parallel to the axis; to simplify the formulae let this light be homogeneous (or white light if the absorption be the same for every species). Let P be the mass of the colouring matter, $\epsilon^{-\mu}$ the coefficient of transmission of its solution, and I_0 the intensity of the incident light, then if I denote the intensity of the transmitted light, we shall have initially

$$I = I_0 \epsilon^{-\mu P} \qquad (1)$$

Now suppose the original body, which we may denote by A, to be gradually changed into another body which we may denote by B, and that ϵ^{-m} is the coefficient of transmission of its solution; let p and q be the masses of A and B existing at any time. Now A must be changed into B in one of three ways, (1) by simple molecular change; in which case the mass of A will be the same as the mass of B, (2) or by the addition of matter (3) or by the subtraction of matter; all these three cases are however included in the formula

$$q = n(P - p). \qquad (2)$$

n being some constant, which in the first case is equal to unity, in the second case greater, and in the third case less

than unity. At any instant the intensity of the transmitted light will be

$$I = I_0 e^{-\mu p - \sigma q}. \qquad (3)$$

Substituting from (2) this becomes

$$I = I_0 e^{-\mu p} e^{q\left(\frac{\mu}{\kappa} - \sigma\right)}.$$

As the composition of the medium is undergoing gradual change, q must be some function of the time, let this be $\phi(t)$, then the last equation may be written

$$I = I_0 e^{-\mu p} e^{c\phi(t)} \qquad (4)$$

The constant c may be either positive or negative, for the transparency of the solution may either diminish or increase; if c have the value o, then a change in chemical composition will have no influence on the nature of the transmitted light. If q be given as a function of the time, then by means of the above formula the intensity of the transmitted light may be determined, and conversely by observations of the intensity we may determine at any time the quantity of B existing in the solution.

There is another enquiry which seems to have more mathematical interest than the preceding, and which was suggested to me some years since when engaged in making experiments with various coloured solutions in order to establish some simple rule for determining quantities by colorimetry, I had occasion to try a solution of potassium ferricyanide, but the action of light on it was so decided, that in a short time, a rule which was satisfactory in some other cases could not be applied to determine the quantity of salt present. The action of light in this and other instances which might be adduced is not of a sudden character, as in the case of the explosion of a mixture of hydrogen and chlorine, but gradual and continuous; when placed in the dark the action is reversed, and the fluid nearly regains its original appearance. What becomes of

absorbed light has long been an interesting question to physicists; from our present knowledge of the transmutation of energy it seems likely that in many cases it is converted into heat, but there are cases in which the transmission of light seems to be attended with structural change of the medium, and this I suppose not to be effected without expenditure of energy. It seems not unlikely that in the case of light we have here something analogous to the *disgregation* of Clausius in the theory of heat. This action of light on the absorptive power of a medium has suggested the investigation of the following problem: *A cylinder contains in solution a body* A *unalterable in the dark, but converted by exposure to light into another body* B, *of different absorptive power; what will be the intensity of the light at any instant transmitted through any section, supposing the light absorbed by* A *to be spent in converting it into* B? As we shall have to deal with partial differential equations, it will facilitate the investigation to suppose the change taking place in a cylinder having opaque sides, and that light of constant intensity is incident on one extremity of the cylinder; by this limitation we shall have to deal with only one dimension of space. Let I_0 be the intensity of the incident light, L the whole length of the cylinder, let the body A be initially uniformly distributed through the cylinder; then if P′ denote the quantity existing initially in a column of length x measured from the extremity admitting light, we shall have

$$P' = \frac{P}{L}x. \qquad (5)$$

Let p and q be quantities of A and B co-existent at any instant in the column x; now the quantity of B formed must be proportional to the quantity of A which has disappeared in the column; therefore we must have the equation

$$q = n(P' - p), \qquad (6)$$

or by substitution from (5)

$$q = n\left(\frac{P}{L}x - p\right) \qquad (7)$$

In this investigation it is supposed that the matter in any section of the cylinder remains in that section after chemical change; it is easy to see that this condition may not always be fulfilled, for the new matter may be of different density from the old, and may rise or sink, so as to pass into a different section; such cases would require a different investigation. I have spoken previously of the bodies being in solution, though this condition is not absolutely necessary; for in a previous paper published in these memoirs, on the absorption of light by turbid media, I have pointed out that in media containing finely divided matter in suspension, the extinction of light by absorption follows the same law as in the clear solutions. Also we might have the body A initially distributed through the cylinder not uniformly, but so that the density in any section shall be some function of the distance of that section from the base of the cylinder; the arbitrary functions of the integral of the differential equation must be adapted to each particular case.

It is supposed that the light absorded by A is spent in converting it into B; from what is known of physical laws it would seem reasonable to infer that the quantity of B produced would be proportional to the quantity of light absorbed. It will therefore be necessary to have some expression for quantity of light; let this be denoted by Q. If light of constant intensity fall for a given time on a given area, it seems reasonable to consider the quantity proportional to the product of the intensity and the time; hence, k being some constant, we shall have the equation

$$Q = kIT, \qquad (8)$$

T denoting the time that the area has been exposed to the light; if the intensity vary during the time T, then if I be the intensity at any instant, for the above equation we must substitute

$$Q = k\int_0^T I dt. \qquad (9)$$

If we have a series of coloured plates, and allow light to pass through them, the result will be the same in whatever order the plates are arranged; this we may apply to determine the intensity of the light passing through the cylinder at any instant; for in each section at any time t after the commencement of the experiment, we shall have the absorbing bodies A and B in different proportions; if we supposed no further change to take place, then at this instant, the intensity of light transmitted through a column of length x would be the same if there were to be a redistribution of A and B, so that all A were collected in one portion of the cylinder, and all B in the other portion; I_0 being the initial intensity of the light, after traversing A, the intensity will become $\epsilon^{-\mu p}$, p being the quantity of A existing at that instant in the length x, then this light after traversing B will have the intensity $I_0\epsilon^{-\mu p - mq}$, q being the quantity of B existing at that instant in the column x; therefore for the transmitted light we shall have the equation

$$I = I_0 e^{-\mu p - mq}. \qquad (10)$$

On account of the variability of p and q with the time, I will vary and at the end of a short time δt will become $I + \delta I$. Now consider a section if the cylinder distant x from the extremity admitting light, and of thickness δx, also let δq and δp be the quantities of B and A simultaneously present in the thin section; since these quantities are variations due to the variation of x, we may, when convenient, substitute for them

$$\frac{dq}{dx}\delta x \text{ and } \frac{dp}{dx}\delta x.$$

After the expiration of a short time δt, the quantities δp and δq will be subject to small variations due to the lapse of time; let these variations be denoted by $\delta\delta p$ and $\delta\delta q$;

then during the short interval δt, the intensity of the light transmitted through the thin plate will lie between

$$I\epsilon^{-\mu\delta p - m\delta q} \text{ and } (I+\delta I)e^{-\mu(\delta p+\delta\delta p)-m(\delta q+\delta\delta q)};$$

and the loss of intensity will lie between

$$I(1-e^{-\mu\delta p-m\delta q}) \text{ and } (I+\delta I)(1-e^{-\mu(\delta p+\delta\delta p)-m(\delta q+\delta\delta q)}).$$

If none of the body A were present in the section the loss of intensity would lie between

$$I(1-\epsilon^{-m\delta q}), \text{ and } (I+\delta I)(1-\epsilon^{-m(\delta q+\delta\delta q)});$$

hence the loss of intensity due to the presence of A in the section will lie between

$$I\epsilon^{-m\delta q}(1-e^{-\mu\delta p}) \text{ and } (I+\delta I)\epsilon^{-m(\delta q+\delta\delta q)}(1-\epsilon^{-\mu(\delta p+\delta\delta p)});$$

now the formation of B is by hypothesis due to the absorption of light by A, the quantity of B present in the thin plate at time t was δq and at time $t+\delta t$, $\delta q+\delta\delta q$, hence the increment due to time δt is $\delta\delta q$, which we may also write in the form

$$\frac{d\delta q}{dt}\delta t;$$

δq as before remarked may be written in the form

$$\frac{dq}{dx}\delta x$$

so that for $\delta\delta q$ we may substitute the expression

$$\frac{d^2q}{dtdx}\delta t\delta x;$$

this will denote the quantity of B formed in the section during the short interval δt. Since quantity of light is proportional to the product of the intensity and the time, from equation (9) it will follow that if we multiply the expressions obtained for the loss of intensity by kdt we shall obtain the limits between which the quantity of light absorbed by the body A in the thin plate during the time dt falls; hence k being some constant, we have

$$\frac{d^2q}{dxdt}\delta x\delta t < kh\mathrm{I}\epsilon^{-m\delta q}(1-e^{-\mu\delta p})\delta t,$$

$$> kh(\mathrm{I}+\delta\mathrm{I})\epsilon^{-m(\delta q+\delta\delta q)}(1-e^{-\mu(\delta p+\delta\delta p)})\delta t.$$

The lower of these expressions may be put in the form

$$kh\mathrm{I}\epsilon^{-m\delta q}(1-e^{-\mu\delta p})\delta t+\mathrm{R},$$

where the letter R denotes a sum of products and powers of small quantities of the third and higher orders; hence the smaller we make δx and δt, the smaller will be the error involved in the equation

$$\frac{d^2q}{dxdt}\delta x\delta t = kh\mathrm{I}\epsilon^{-m\delta q}(1-e^{-\mu\delta p})\delta t. \qquad (11)$$

$\epsilon^{-m\delta q}$ may be written in the form

$$\epsilon^{-m\frac{dq}{dx}\delta x};$$

or if we expand

$$1-m\frac{dq}{dx}\delta x+\frac{m^2}{2}\left(\frac{dq}{dx}\right)^2\delta x^2-\&c.;$$

and $1-\epsilon^{-\mu\delta p}$ may be written in the form

$$1-e^{-\mu\frac{dp}{dx}\delta x}$$

or if we expand

$$\mu\frac{dp}{dx}\delta x-\frac{\mu^2}{2}\left(\frac{dh}{dx}\right)^2\delta x^2+\&c.;$$

therefore (11) may be written

$$\frac{d^2q}{dxdt}\delta x\delta t = kh\mathrm{I}\left(1-m\frac{dq}{dx}\delta x+\frac{m^2}{2}\left(\frac{dq}{dn}\right)^2\delta x^2-\&c.\right)$$

$$\left(\mu\frac{dp}{dx}\delta x-\frac{\mu^2}{2}\left(\frac{dp}{dx}\right)^2\delta x^2+\&c.\right)\delta t; \qquad (12)$$

if we effect the multiplication of the two polynomials on the right side, then divide both sides of the equation by $\delta x\delta t$, and then suppose δx and δt to be diminished indefinitely, we arrive at the following partial differential equation

$$\frac{d^2q}{dxdt} = kh\mathrm{I}\mu\frac{dp}{dx}. \qquad (13)$$

From (7) by differentiation we obtain

$$\frac{d^2q}{dxdt} = -n\frac{d^2p}{dxdt}; \qquad (14)$$

substituting for

$$\frac{d^2q}{dxdt}$$

in (13), and replacing I by its value from (10), equation (13) assumes the form

$$-n\frac{d^2p}{dxdt} = kh\mu I_o e^{-\mu p - mq}\frac{dp}{dx}$$

now replace q by its value in terms of p by (7), then the equation may be presented in the form

$$\frac{d^2p}{dxdt} = -a\frac{dp}{dx}e^{pc-bx}, \qquad (15)$$

in which for brevity a has been written for

$$\frac{khI_o\mu}{n},\ b \text{ for } \frac{mnP}{L},$$

and c for $mn-\mu$.

The last equation may be transformed in several ways; it may be written in the form

$$\frac{d}{dt}\log\frac{dp}{dx} = -ae^{pc-bx}; \qquad (16)$$

by differentiation with respect to x this becomes

$$\frac{d^2}{dxdt}\log\frac{dp}{dx} = -ae^{pc-bx}\left(c\frac{dp}{dx}-b\right); \qquad (17)$$

by substitution from (16), the last equation may be written

$$\frac{d^2}{dxdt}\log\frac{dp}{dx} = \frac{d}{dt}\log\frac{dp}{dx}\cdot\left(c\frac{dp}{dx}-b\right); \qquad (18)$$

integrating with respect to t, and adding an arbitrary function of x, we obtain the following equation in which t does not appear

$$\frac{d^2p}{dx^2} = \frac{dp}{dx}\left(c\frac{dp}{dx} - b\log\frac{dp}{dx} + \phi(x)\right); \qquad (19)$$

this equation does not seem to be further integrable. Reverting to (15), assume the following equation

$$p = U_0 + U_1x + U_2x^2 + U_3x^3 + U_4x^4 + \&c.; \qquad (20)$$

wherein the coefficients U_0, U_1, U_2 &c., may be functions of t. Differentiating with respect to x we obtain

$$\frac{dp}{dx} = U_1 + 2U_2x + 3U_3x^2 + 4U_4x^3 + 5U_5x^4 + \&c.; \qquad (21)$$

denoting differentiation with respect to t by using accented letters, from the last equation we obtain

$$\frac{d^2p}{dtdx} = U'_1 + 2U'_2x + 3U'_3x^2 + 4U'_4x^3 + 5U'_5x^4 + \&c. \qquad (22)$$

Equation (15) may be written in the form

$$\log\frac{d^2p}{dxdt} - \log\frac{dp}{dx} = \log(-a) + cp - bx; \qquad (23)$$

substituting from (20), (21), and (22) in the last equation we obtain

$$\log(U'_1 + 2U'_2x + 3U'_3x^2 + \&c.) - \log(U_1 + 2U_2x + 3U_3x^2 + \&c.)$$
$$= \log(-a) + cU_0 + x(cU_1 - b) + cU_2x^2 + cU_3x^3 + cU_4x^4 - \&c. \qquad (24)$$

Expand $\log(U_1+2U_2x+3U_3x^2+\&c.)$ in a series of powers of x; put V for $2U_2x+3U_3x^2+\&c.$; then when x vanishes V also vanishes, hence the first term in the expansion of $\log(U_1+V)$ will be $\log U_1$; the coefficient of x will be

$$\left\{\frac{1}{U_1+V}\frac{dV}{dx}\right\}_{x=0}, \text{ and of } x^2, \frac{1}{2}\left\{\frac{d}{dx}\left(\frac{1}{U_1+V}\frac{dV}{dx}\right)\right\}_{x=0},$$

and generally the coefficient of x^{n+1} will be

$$\frac{1}{\underline{n+1}}\left\{\frac{d_n}{dx^n}\left(\frac{1}{U_1+V}\frac{dV}{dx}\right)\right\}_{x=0}$$

assume

$$\frac{1}{U_1+V} = A_0 + A_1x + A_2x^2 + A_3x^3 + A_4x^4 + \&c.; \qquad (25)$$

if A_n be the coefficient of x^n in this expansion we shall have

$$A_n = \frac{1}{\underline{n}}\left\{\frac{d^n}{dx^n}\left(\frac{1}{U_1+V}\right)\right\}_{x=0}. \qquad (26)$$

From the equation

$$V = 2U_2x + 3U_3x^2 + 4U_4x^3 + 5U_5x^4 + \&c., \qquad (27)$$

we shall obtain by differentiation

$$U_{n+1}|\underline{n+1} = \left\{\frac{d^n V}{dx^n}\right\}_{x=0}, \qquad (28)$$

To find the value of

$$\frac{d^n}{dx^n}\left(\frac{1}{U_1+V}\,\frac{dV}{dx}\right),$$

we may apply the theorem of Leibnitz for finding the n^{th} differential coefficient of the product of two functions of x; if in this result we make $x=o$ we obtain the equation

$$\begin{aligned}\left\{\frac{d^n}{dx^n}\left(\frac{1}{U_1+V}\,\frac{dV}{dx}\right)\right\}_{x=0} = n[&A_0(n+1)(n+2)U_{n+2}\\ &+ A_1 n(n+1)U_{n+1} + A_2(n-1)nU_n + \&\\ &+ A_r(n-r+1)(n-r+2)U_{n-r+2}\\ &+ A_{r+1}(n-r)(n-r+1)U_{n-r+1} + \&c. + A_n 2U_2]. \qquad (29)\end{aligned}$$

Hence the coefficient of x^{n+1} in the expansion of $\log(U_1+V)$ will be

$$\begin{aligned}\frac{1}{n+1}[&A_0(n+1)(n+2)U_{n+2} + A_1 n(n+1)U_{n+1}\\ &+ A_2 n(n-1)U_n + \&c. + A_n 2U_2\,;\end{aligned}$$

giving to n the values 0, 1, 2, 3, 4, we shall obtain the following results—

Coefficient of

$$x = 2A_0U_2$$

$$,, \quad x^2 = \frac{1}{2}(A_0 3\cdot 2U_3 + A_1 2U_2)$$

$$,, \quad x^3 = \frac{1}{3}(A_0 4\cdot 3U_4 + A_1 3\cdot 2U_3 + A_2 2U_2)$$

$$,, \quad x^4 = \frac{1}{4}(A_0 5\cdot 4U_5 + A_1 4\cdot 3U_4 + A_2 3\cdot 2U_3 + A_3 2U_2)$$

$$,, \quad x^5 = \frac{1}{5}(A_0 6\cdot 5U_6 + A_1 5\cdot 4U_5 + A_2 4\cdot 3U_4 + A_3 3\cdot 2U_3 + A_4 2U_2)\,;$$

by a continuation of the process expressions might be found for the remaining coefficients.

To determine the values of the letters A_0, A_1, A_2 &c. in terms of U_1, U_2, U_3 &c., we may proceed as follows; substituting for V its value in terms of x from (27), then from

(25) we shall get

$$1 = (U_1 + 2U_2x + 3U_3x^2 + 4U_4x^3 + , \text{ \&c.})\ (A_0 + A_1x + A_2x^2 + A_3x^3 + \text{\&c.}); \quad (30)$$

effecting the multiplication, and arranging the result in ascending powers of x we shall obtain

$$\begin{aligned} 1 = {} & A_0U_1 + x(A_02U_2 + A_1U_1) \\ & + x^2(A_03E_3 + A_12U_2 + A_2U_1) + x^3(A_04U_4 + A_13U_3 + A_22U_2 + A_3U_1) \\ & + x^4(A_05U_5 + A_14U_4 + A_23U_3 + A_32U_2 + A_4U_1) \\ & + x^5(A_06U_6 + A_15U_5 + A_24U_4 + A_33U_3 + A_42U_2 + A_5U_1) \\ & + , \text{ \&c. ;} \end{aligned} \quad (31)$$

as this equation holds for all values of x we shall have

$$A_0U_1 = 1 \quad (32)$$

$$2U_2A_0 + A_1U_1 = 0 \quad (33)$$

$$3U_3A_0 + 2U_2A_1 + U_1A_2 = 0 \quad (34)$$

$$4U_4A_0 + 3U_3A_1 + 2U_2A_2 + U_1A_3 = 0 \quad (35)$$

$$5U_5A_0 + 4U_4A_1 + 3U_3A_2 + 2U_2A_3 + U_1A_4 = 0 \quad (36)$$

The general equation being

$$nU_nA_0 + (n-1)U_{n-1}A_1 + (n-2)U_{n-2}A_2 + \text{ \&c. } + U_1A_{n-1} = 0 \quad (37)$$

From (32) we obtain

$$A_0 = \frac{1}{U_1};$$

substituting this value in (33) we obtain

$$A_1 = -\frac{2U_2}{U_1^2};$$

substitute these values of A_0, A_1, in (34), then

$$A_2 = \frac{4U_2^2}{U_1^3} - \frac{3U_3}{U_1^2};$$

these values of A_0, A_1, A_2, being substituted in (35), then

$$A_3 = -\frac{4U_4}{U_1^2} + \frac{12U_2U_3}{U_1^3} - \frac{8U_2^3}{U_1^4}$$

substitute these values of A_0, A_1, A_2, A_3 in (36), then

$$A_4 = -\frac{5U_5}{U_1^2} + \frac{16U_4U_2}{U_1^3} - \frac{36U_3U_2^2}{U_1^4} + \frac{9U_3^2}{U_1^3} + \frac{16U_2^4}{U_1^5}.$$

By a continuation of this process the values of the

succeeding letters A_2, A_3 &c., may be found in terms of the letters U_1, U_2, U_3 &c. These values of A_1, A_2 &c., being substituted in the expressions previously obtained for the various powers of x, we obtain the following results

coefficient of $x = \frac{2U_2}{U_1}$

" $x^2 = \frac{3U_3}{U_1} - \frac{2U_2^2}{U_1^2}$

" $x^3 = \frac{1}{3}\left(\frac{12U_4}{U_1} - \frac{18U_3U_2}{U_1^2} + \frac{8U_2^3}{U_1^3}\right)$

" $x^4 = \frac{1}{4}\left(\frac{20U_5}{U_1} - \frac{32U_4U_2}{U_1^2} - \frac{18U_3^2}{U_1^2} + \frac{48U_3U_2^2}{U_1^3} - \frac{16U_2^4}{U_1^4}\right)$

" $x^5 = \frac{1}{5}\left(\frac{30U_6}{U_1} - \frac{50U_5U_2}{U_1^2} - \frac{60U_4U_3}{U_1^2} + \frac{80U_4U_2^2}{U_1^3} + \frac{90U_3^2U_2}{U_1^3} - \frac{120U_3U_2^3}{U_1^4} + \frac{32U_2^5}{U_1^5}\right)$

by a continuation of the process the coefficients of the other powers of x may be determined.

If we expand

$$\log \frac{d^2p}{dx\,dt} \text{ or } \log(U_1' + 2U_2'x + 3U_3'x^2 + \&c.$$

in powers of x, the result will differ from the result already obtained in this respect only, for the letters U_1, U_2, U_3 &c., the accented letters U_1', U_2', U_3', &c., must be used; hence we shall have the equation—

$$\log \frac{d^2p}{dx\,dt} - \log \frac{dp}{dx} = \log U_1' - \log U_1 + x2\left(\frac{U_2'}{U_1'} - \frac{U_2}{U_1}\right)$$

$$+ x^2\left\{3\left(\frac{U_3'}{U_1'} - \frac{U_3}{U_1}\right) - 2\left(\frac{(U_2')^2}{(U_1')^2} - \frac{U_2^2}{U_1^2}\right)\right\} + \frac{x^3}{3}\left\{12\left(\frac{U_4'}{U_1'} - \frac{U_4}{U_1}\right)\right.$$

$$\left. - 18\left(\frac{U_3'U_2'}{(U_1')^2} - \frac{U_3U_2}{U_1^2}\right) + 8\left(\frac{(U_2')^3}{(U_1')^3} - \frac{U_2^3}{U_1^3}\right)\right\} + \frac{x^4}{4}\left\{20\left(\frac{U_5'}{U_1'} - \frac{U_5}{U_1}\right)\right.$$

$$\left. - 32\left(\frac{U_4'U_2'}{(U_1')^2} - \frac{U_4U_2}{U_1^2}\right) - 18\left(\frac{(U_3')^2}{(U_1')^2} - \frac{U_3^2}{U_1^2}\right) + 48\left(\frac{U_3'(U_2')^2}{(U_1')^3} - \frac{U_3U_2^2}{U_1^3}\right)\right.$$

$$Q = k\int_0^T I dt. \qquad (9)$$

If we have a series of coloured plates, and allow light to pass through them, the result will be the same in whatever order the plates are arranged; this we may apply to determine the intensity of the light passing through the cylinder at any instant; for in each section at any time t after the commencement of the experiment, we shall have the absorbing bodies A and B in different proportions; if we supposed no further change to take place, then at this instant, the intensity of light transmitted through a column of length x would be the same if there were to be a redistribution of A and B, so that all A were collected in one portion of the cylinder, and all B in the other portion; I_0 being the initial intensity of the light, after traversing A, the intensity will become $\epsilon^{-\mu p}$, p being the quantity of A existing at that instant in the length x, then this light after traversing B will have the intensity $I_0\epsilon^{-\mu p - mq}$, q being the quantity of B existing at that instant in the column x; therefore for the transmitted light we shall have the equation

$$I = I_0 e^{-\mu p - mq}. \qquad (10)$$

On account of the variability of p and q with the time, I will vary and at the end of a short time δt will become $I + \delta I$. Now consider a section if the cylinder distant x from the extremity admitting light, and of thickness δx, also let δq and δp be the quantities of B and A simultaneously present in the thin section; since these quantities are variations due to the variation of x, we may, when convenient, substitute for them

$$\frac{dq}{dx}\delta x \text{ and } \frac{dp}{dx}\delta x.$$

After the expiration of a short time δt, the quantities δp and δq will be subject to small variations due to the lapse of time; let these variations be denoted by $\delta\delta p$ and $\delta\delta q$;

then during the short interval δt, the intensity of the light transmitted through the thin plate will lie between

$$I_t\, ^{-\mu\lambda p - m\lambda q} \text{ and } (I + \delta I)e^{-\mu(\lambda p + \lambda\lambda p) - m(\lambda q + \lambda\lambda q)};$$

and the loss of intensity will lie between

$$I(1 - e^{-\mu\lambda p - m\lambda q}) \text{ and } (I + \delta I)(1 - e^{-\mu(\lambda p + \lambda\lambda p) - m(\lambda q + \lambda\lambda q)}).$$

If none of the body A were present in the section the loss of intensity would lie between

$$I(1 - e^{-m\lambda q}), \text{ and } (I + \delta I)(1 - e^{-m(\lambda q + \lambda\lambda q)});$$

hence the loss of intensity due to the presence of A in the section will lie between

$$I_t\, ^{-m\lambda q}(1 - e^{-\mu\lambda p}) \text{ and } (I + \delta I)e^{-m(\lambda q + \lambda\lambda q)}(1 - e^{-\mu(\lambda p + \lambda\lambda p)});$$

now the formation of B is by hypothesis due to the absorption of light by A, the quantity of B present in the thin plate at time t was δq and at time $t + \delta t$, $\delta q + \delta\delta q$, hence the increment due to time δt is $\delta\delta q$, which we may also write in the form

$$\frac{d\delta q}{dt}\delta t;$$

δq as before remarked may be written in the form

$$\frac{dq}{dx}\delta x$$

so that for $\delta\delta q$ we may substitute the expression

$$\frac{d^2q}{dtdx}\lambda t\delta x;$$

this will denote the quantity of B formed in the section during the short interval δt. Since quantity of light is proportional to the product of the intensity and the time, from equation (9) it will follow that if we multiply the expressions obtained for the loss of intensity by $k dt$ we shall obtain the limits between which the quantity of light absorbed by the body A in the thin plate during the time dt falls; hence k being some constant, we have

$$\frac{d^2q}{dxdt}\delta x\delta t < kh\mathrm{I}\varepsilon^{-m\delta q}(1-e^{-\mu\delta p})\delta t,$$

$$> kh(\mathrm{I}+\delta\mathrm{I})\varepsilon^{-m(\delta q+\delta\delta q)}(1-e^{-\mu(\delta p+\delta\delta p)})\delta t.$$

The lower of these expressions may be put in the form

$$kh\mathrm{I}\varepsilon^{-m\delta q}(1-e^{-\mu\delta p})\delta t+\mathrm{R},$$

where the letter R denotes a sum of products and powers of small quantities of the third and higher orders; hence the smaller we make δx and δt, the smaller will be the error involved in the equation

$$\frac{d^2q}{dxdt}\delta x\delta t = kh\mathrm{I}\varepsilon^{-m\delta q}(1-e^{-\mu\delta p})\delta t. \qquad (11)$$

$\varepsilon^{-m\delta q}$ may be written in the form

$$\varepsilon^{-m\frac{dq}{dx}\delta x};$$

or if we expand

$$1-m\frac{dq}{dx}\delta x+\frac{m^2}{2}\left(\frac{dq}{dx}\right)^2\delta x^2-\&c.;$$

and $1-\varepsilon^{-\mu\delta p}$ may be written in the form

$$1-e^{-\mu\frac{dp}{dx}\delta x}$$

or if we expand

$$\mu\frac{dp}{dx}\delta x-\frac{\mu^2}{2}\left(\frac{dh}{dx}\right)^2\delta x^2+\&c.;$$

therefore (11) may be written

$$\frac{d^2q}{dxdt}\delta x\delta t = kh\mathrm{I}\left(1-m\frac{dq}{dx}\delta x+\frac{m^2}{2}\left(\frac{dq}{dn}\right)^2\delta x^2-\&c.\right)$$

$$\left(\mu\frac{dp}{dx}\delta x-\frac{\mu^2}{2}\left(\frac{dp}{dx}\right)^2\delta x^2+\&c.\right)\delta t; \qquad (12)$$

if we effect the multiplication of the two polynomials on the right side, then divide both sides of the equation by $\delta x\delta t$, and then suppose δx and δt to be diminished indefinitely, we arrive at the following partial differential equation

$$\frac{d^2q}{dxdt} = kh\mathrm{I}\mu\frac{dp}{dx}. \qquad (13)$$

From (7) by differentiation we obtain

$$\frac{d^2q}{dxdt} = -n\frac{d^2p}{dxdt}; \qquad (14)$$

substituting for

$$\frac{d^2q}{dxdt}$$

in (13), and replacing I by its value from (10), equation (13) assumes the form

$$-n\frac{d^2p}{dxdt} = kh\mu I_0 e^{-\mu p - mq}\frac{dp}{dx}$$

now replace q by its value in terms of p by (7), then the equation may be presented in the form

$$\frac{d^2p}{dxdt} = -a\frac{dp}{dx}e^{pc-bx}, \qquad (15)$$

in which for brevity a has been written for

$$\frac{kh\mathrm{I}_0\mu}{n}, \; b \text{ for } \frac{mn\mathrm{I}^0}{\mathrm{L}},$$

and c for $mn-\mu$.

The last equation may be transformed in several ways; it may be written in the form

$$\frac{d}{dt}\log\frac{dp}{dx} = -ae^{pc-bx}; \qquad (16)$$

by differentiation with respect to x this becomes

$$\frac{d^2}{dxdt}\log\frac{dp}{dx} = -ae^{pc-bx}\left(c\frac{dp}{dx}-b\right); \qquad (17)$$

by substitution from (16), the last equation may be written

$$\frac{d^2}{dxdt}\log\frac{dp}{dx} = \frac{d}{dt}\log\frac{dp}{dx}\cdot\left(c\frac{dp}{dx}-b\right); \qquad (18)$$

integrating with respect to t, and adding an arbitrary function of x, we obtain the following equation in which t does not appear

$$\frac{d^2p}{dx^2} = \frac{dp}{dx}\left(c\frac{dp}{dx} - b\log\frac{dp}{dx} + \phi(x)\right); \qquad (19)$$

this equation does not seem to be further integrable. Reverting to (15), assume the following equation

$$p = U_0 + U_1 x + U_2 x^2 + U_3 x^3 + U_4 x^4 + \&c.; \qquad (20)$$

wherein the coefficients U_0, U_1, U_2 &c., may be functions of t. Differentiating with respect to x we obtain

$$\frac{dp}{dx} = U_1 + 2U_2 x + 3U_3 x^2 + 4U_4 x^3 + 5U_5 x^4 + \&c.; \qquad (21)$$

denoting differentiation with respect to t by using accented letters, from the last equation we obtain

$$\frac{d^2p}{dtdx} = U'_1 + 2U'_2 x + 3U'_3 x^2 + 4U'_4 x^3 + 5U'_5 x^4 + \&c. \qquad (22)$$

Equation (15) may be written in the form

$$\log\frac{d^2p}{dxdt} - \log\frac{dp}{dx} = \log(-a) + cp - bx; \qquad (23)$$

substituting from (20), (21), and (22) in the last equation we obtain

$$\log(U'_1 + 2U'_2 x + 3U'_3 x^2 + \&c.) - \log(U_1 + 2U_2 x + 3U_3 x^2 + \&c.)$$
$$= \log(-a) + cU_0 + x(cU_1 - b) + cU_2 x^2 + cU_3 x^3 + cU_4 x^4 - \&c. \qquad (24)$$

Expand $\log(U_1 + 2U_2 x + 3U_3 x^2 + \&c.)$ in a series of powers of x; put V for $2U_2 x + 3U_3 x^2 + \&c.$; then when x vanishes V also vanishes, hence the first term in the expansion of $\log(U_1 + V)$ will be $\log U_1$; the coefficient of x will be

$$\left\{\frac{1}{U_1 + V}\,\frac{dV}{dx}\right\}_{x=0}, \text{ and of } x^2, \frac{1}{2}\left\{\frac{d}{dx}\left(\frac{1}{U_1 + V}\,\frac{dV}{dx}\right)\right\}_{x=0},$$

and generally the coefficient of x^{n+1} will be

$$\frac{1}{n+1}\left\{\frac{d_n}{dx^n}\left(\frac{1}{U_1 + V}\,\frac{dV}{dx}\right)\right\}_{x=0}$$

assume

$$\frac{1}{U_1 + V} = A_0 + A_1 x + A_2 x^2 + A_3 x^3 + A_4 x^4 + \&c.; \qquad (25)$$

if A_n be the coefficient of x^n in this expansion we shall have

$$A_n = \frac{1}{\underline{n}}\left\{\frac{d^n}{dx^n}\left(\frac{1}{U_1 + V}\right)\right\}_{x=0}. \qquad (26)$$

From the equation

$$V = 2U_2 x + 3U_3 x^2 + 4U_4 x^3 + 5U_5 x^4 + \&c., \qquad (27)$$

we shall obtain by differentiation

$$U_{n+1}\underline{|n+1} = \left\{\frac{d^n V}{dx^n}\right\}_{x=0}, \qquad (28)$$

To find the value of

$$\frac{d^n}{dx^n}\left(\frac{1}{U_1+V}\frac{dV}{dx}\right),$$

we may apply the theorem of Leibnitz for finding the n^{th} differential coefficient of the product of two functions of x; if in this result we make $x=o$ we obtain the equation

$$\begin{aligned}\left\{\frac{d^n}{dx^n}\left(\frac{1}{U_1+V}\frac{dV}{dx}\right)\right\}_{x=0} = n[&A_0(n+1)(n+2)U_{n+2}\\ &+ A_1 n(n+1)U_{n+1} + A_2(n-1)nU_n + \&c\\ &+ A_r(n-r+1)(n-r+2)U_{n-r+2}\\ &+ A_{r+1}(n-r)(n-r+1)U_{n-r+1} + \&c. + A_n 2U_2]. \qquad (29)\end{aligned}$$

Hence the coefficient of x^{n+1} in the expansion of $\log(U_1+V)$ will be

$$\begin{aligned}\frac{1}{n+1}[&A_0(n+1)(n+2)U_{n+2} + A_1 n(n+1)U_{n+1}\\ &+ A_2 n(n-1)U_n + \&c. + A_n 2U_2;\end{aligned}$$

giving to n the values 0, 1, 2, 3, 4, we shall obtain the following results—

Coefficient of

$$x = 2A_0U_2$$

$$,, \quad x^2 = \frac{1}{2}(A_0 3\cdot 2U_3 + A_1 2U_2)$$

$$,, \quad x^3 = \frac{1}{3}(A_0 4\cdot 3U_4 + A_1 3\cdot 2U_3 + A_2 2U_2)$$

$$,, \quad x^4 = \frac{1}{4}(A_0 5\cdot 4U_5 + A_1 4\cdot 3U_4 + A_2 3\cdot 2U_3 + A_3 2U_2)$$

$$,, \quad x^5 = \frac{1}{5}(A_0 6\cdot 5U_6 + A_1 5\cdot 4U_5 + A_2 4\cdot 3U_4 + A_3 3\cdot 2U_3 + A_4 2U_2);$$

by a continuation of the process expressions might be found for the remaining coefficients.

To determine the values of the letters A_0, A_1, A_2 &c. in terms of U_2, U_3, U_4 &c., we may proceed as follows; substituting for V its value in terms of x from (27), then from

(25) we shall get

$$1 = (U_1 + 2U_2x + 3U_3x^2 + 4U_4x^3 + , \&c.)$$
$$(A_0 + A_1x + A_2x^2 + A_3x^3 + \&c.); \quad (30)$$

effecting the multiplication, and arranging the result in ascending powers of x we shall obtain

$$\begin{aligned} 1 = {} & A_0U_1 + x(A_02U_2 + A_1U_1) \\ & + x^2(A_03E_3 + A_12U_2 + A_2U_1) + x^3(A_04U_4 + A_13U_3 + A_22U_2 + A_3U_1) \\ & + x^4(A_05U_5 + A_14U_4 + A_23U_3 + A_32U_2 + A_4U_1) \\ & + x^5(A_06U_6 + A_15U_5 + A_24U_4 + A_33U_3 + A_42U_2 + A_5U_1) \\ & + , \&c. ; \end{aligned} \quad (31)$$

as this equation holds for all values of x we shall have

$$A_0U_1 = 1 \quad (32)$$
$$2U_2A_0 + A_1U_1 = 0 \quad (33)$$
$$3U_3A_0 + 2U_2A_1 + U_1A_2 = 0 \quad (34)$$
$$4U_4A_0 + 3U_3A_1 + 2U_2A_2 + U_1A_3 = 0 \quad (35)$$
$$5U_5A_0 + 4U_4A_1 + 3U_3A_2 + 2U_2A_3 + U_1A_4 = 0 \quad (36)$$

The general equation being

$$nU_nA_0 + (n-1)U_{n-1}A_1 + (n-2)U_{n-2}A_2 + \&c. + U_1A_{n-1} = 0 \quad (37)$$

From (32) we obtain

$$A_0 = \frac{1}{U_1};$$

substituting this value in (33) we obtain

$$A_1 = -\frac{2U_2}{U_1^2};$$

substitute these values of A_0, A_1, in (34), then

$$A_2 = \frac{4U_2^2}{U_1^3} - \frac{3U_3}{U_1^2};$$

these values of A_0, A_1, A_2, being substituted in (35), then

$$A_3 = -\frac{4U_4}{U_1^2} + \frac{12U_3U_2}{U_1^3} - \frac{8U_2^3}{U_1^4}$$

substitute these values of A_0, A_1, A_2, A_3 in (36), then

$$A_4 = -\frac{5U_5}{U_1^2} + \frac{16U_4U_2}{U_1^3} - \frac{36U_3U_2^2}{U_1^4} + \frac{9U_3^2}{U_1^3} + \frac{16U_2^4}{U_1^5}.$$

By a continuation of this process the values of the

succeeding letters A_2, A_3 &c., may be found in terms of the letters U_1, U_2, U_3 &c. These values of A_1, A_2 &c., being substituted in the expressions previously obtained for the various powers of x, we obtain the following results

coefficient of $x = \frac{2U_2}{U_1}$

" $x^2 = \frac{3U_3}{U_1} - \frac{2U_2^2}{U_1^2}$

" $x^3 = \frac{1}{3}\left(\frac{12U_4}{U_1} - \frac{18U_3U_2}{U_1^2} + \frac{8U_2^3}{U_1^3}\right)$

" $x^4 = \frac{1}{4}\left(\frac{20U_5}{U_1} - \frac{32U_4U_2}{U_1^2} - \frac{18U_3^2}{U_1^2} + \frac{48U_3U_2^2}{U_1^3} - \frac{16U_2^4}{U_1^4}\right)$

" $x^5 = \frac{1}{5}\left(\frac{30U_6}{U_1} - \frac{50U_5U_2}{U_1^2} - \frac{60U_4U_3}{U_1^2} + \frac{80U_4U_2^2}{U_1^3} + \frac{90U_3^2U_2}{U_1^3} - \frac{120U_3U_2^3}{U_1^4} + \frac{32U_2^5}{U_1^5}\right)$

by a continuation of the process the coefficients of the other powers of x may be determined.

If we expand

$$\log \frac{d^2p}{dx\,dt} \text{ or } \log(U_1^1 + 2U_2^1x + 3U_3^1x^2 + \&c.$$

in powers of x, the result will differ from the result already obtained in this respect only, for the letters U_1, U_2, U_3 &c., the accented letters U_1^1, U_2^1, U_3^1, &c., must be used; hence we shall have the equation—

$$\log \frac{d^2p}{dx\,dt} - \log \frac{dp}{dx} = \log U_1^1 - \log U_1 + x2\left(\frac{U_2^1}{U_1^1} - \frac{U_2}{U_1}\right)$$

$$+ x^2\left\{3\left(\frac{U_3^1}{U_1^1} - \frac{U_3}{U_1}\right) - 2\left(\frac{(U_2^1)^2}{(U_1^1)^2} - \frac{U_2^2}{U_1^2}\right)\right\} + \frac{x^3}{3}\left\{12\left(\frac{U_4^1}{U_1^1} - \frac{U_4}{U_1}\right)\right.$$

$$\left. - 18\left(\frac{U_3^1U_2^1}{(U_1^1)^2} - \frac{U_3U_2}{U_1^2}\right) + 8\left(\frac{(U_2^1)^3}{(U_1^1)^3} - \frac{U_2^3}{U_1^3}\right)\right\} + \frac{x^4}{4}\left\{20\left(\frac{U_5^1}{U_1^1} - \frac{U_5}{U_1}\right)\right.$$

$$\left. - 32\left(\frac{U_4^1U_2^1}{(U_1^1)^2} - \frac{U_4U_2}{U_1^2}\right) - 18\left(\frac{(U_3^1)^2}{(U_1^1)^2} - \frac{U_3^2}{U_1^2}\right) + 48\left(\frac{U_3^1(U_2^1)^2}{(U_1^1)^3} - \frac{U_3U_2^2}{U_1^3}\right)\right.$$

$$-16\left(\frac{(U_2^1)^4}{(U_1^1)^4}-\frac{U_2^4}{U_1^4}\right)\Big\}+\frac{x^5}{5}\Big\{30\left(\frac{U_5^1}{U_1^1}-\frac{U_5}{U_1}\right)-50\left(\frac{U_3^1U_2^1}{(U_1^1)^3}-\frac{U_3U_2}{U_1^3}\right)$$

$$+80\left(\frac{U_4^1(U_2^1)^2}{(U_1^1)^3}-\frac{U_4U_2}{U_1^2}\right)-60\left(\frac{U_4^1U_2^1}{(U_1^1)^3}-\frac{U_4U_2}{U_1^3}\right)$$

$$+90\left(\frac{(U_2^1)^3U_2^1}{(U_1^1)^5}-\frac{U_2^2U_2}{U_1^3}\right)-120\left(\frac{U_2^1(U_2^1)^3}{(U_1^1)^4}-\frac{U_2U_2^3}{U_1^4}\right)$$

$$+32\left(\frac{(U_2^1)^5}{(U_1^1)^5}-\frac{U_2^5}{U_1^5}\right)\Big\}+\&c.$$

By (24), this expansion is equal to

$$\log(-a)+cU_0+x(cU_1-b)+cU_2x^2+cU_3x^3+cU_4x^4+cU_5x^5+\&c.;$$

hence if we equate the coefficients of corresponding powers of x we shall obtain the following equations—

$$\log U_1^1-\log U_1=\log -a+cU_0$$

$$2\left(\frac{U_2^1}{U_1^1}-\frac{U_2}{U_1}\right)=cU_1-b$$

$$3\left(\frac{U_3^1}{U_1^1}-\frac{U_3}{U_1}\right)-2\left(\frac{(U_2^1)}{(U_1^1)}-\frac{U_2}{U_1^2}\right)=cU_2$$

$$\frac{1}{3}\Big\{12\left(\frac{U_4^1}{U_1^1}-\frac{U_4}{U_1}\right)-18\left(\frac{U_3^1U_2^1}{(U_1^1)^2}-\frac{U_3U_2}{U_1^3}\right)+8\left(\frac{(U_2^1)^3}{(U_1^1)^3}-\frac{U_2^3}{U_1^3}\right)\Big\}=cU_3$$

$$\frac{1}{4}\Big\{20\left(\frac{U_5^1}{U_1^1}-\frac{U_5}{U_1}\right)-32\left(\frac{U_4^1U_2^1}{(U_1^1)^2}-\frac{U_4U_2}{U_1^3}\right)-18\left(\frac{(U_2^1)^2}{(U_1^1)^2}-\frac{U_2^2}{U_1^3}\right)$$

$$+48\left(\frac{U_3^1(U_2^1)^2}{(U_1^1)^3}-\frac{U_3U_2^2}{U_1^3}\right)-16\left(\frac{(U_2^1)^4}{(U_1^1)^4}-\frac{U_2^4}{U_1^4}\right)\Big\}=cU_4$$

$$\frac{1}{5}\Big\{30\left(\frac{U_6^1}{U_1^1}-\frac{U_6}{U_1}\right)-50\left(\frac{U_5^1U_2^1}{(U_1^1)^2}-\frac{U_5U_2}{U_1^3}\right)+80\left(\frac{U_4^1(U_2^1)^2}{(U_1^1)^3}-\frac{U_4U_2^2}{U_1^3}\right)$$

$$-60\left(\frac{U_4^1U_3^1}{(U_1^1)^2}-\frac{U_4U_3}{U_1^2}\right)+90\left(\frac{(U_2^1)^3U_2^1}{(U_1^1)^5}-\frac{U_2^3U_2}{U_1^3}\right)$$

$$-120\left(\frac{(U_2^1)^3U_2^1}{(U_1^1)^4}-\frac{U_2U_3}{U_1^4}\right)+32\left(\frac{(U_2^1)^5}{(U_1^1)^5}-\frac{U_2^5}{U_1^5}\right)\Big\}=cU_5.$$

In a similar manner the relationship of the coefficients of higher powers of x may be determined; the expressions so obtained become more complicated.

Now consider the first of this series of equations

$$\log U_1^1-\log U=\log -a+cU_0$$

by the accent differentiation with respect to t is denoted so that for U_1' we may write

$$\frac{dU_1}{dt};$$

then the equation may be put in the form

$$\log\left(-\frac{1}{aU_1}\frac{dU_1}{dt}\right) = cU_0$$

or in the form

$$\frac{1}{U_1}\frac{dU_1}{dt} = -ae^{cU_0};$$

integrating this equation we obtain

$$U_1 = r_1 e^{-a\int e^{cU_0}dt} \tag{37}$$

r_1 denoting some arbitrary constant, also U_0 is by hypothesis some function of the time, but as yet undetermined, hence for simplicity the last equation may be written in the form

$$U_1 = r_1 e^{-a\phi(t)}. \tag{38}$$

Next consider the second equations of the series

$$2\left(\frac{U_2'}{U_1'} - \frac{U_2}{U_1}\right) = cU_1 - b; \tag{39}$$

if in this equation we write

$$\frac{dU_2}{dt} \text{ for } U_2', \text{ and } \frac{dU_1}{dt} \text{ for } U_1',$$

we shall obtain on integration

$$U_2 = U_1\left(\frac{1}{2}\int \frac{d\log U_1}{dt}(cU_1 - b)\,dt + r_2\right), \tag{40}$$

r_2 being some arbitrary constant; if the integration be completed we shall obtain

$$U_2 = U_1\left(\frac{cU_1 - b\log U_1}{2} + r_2\right) \tag{41}$$

but U_1 has already been obtained as a function of U_0, hence by substitution U_2 will be obtained as a function of U_0. Next consider the third equation of the series

$$3\left(\frac{U_3'}{U_1'} - \frac{U_3}{U_1}\right) - 2\left(\frac{(U_2')^2}{(U_1')^2} - \frac{U_2^2}{U_1^2}\right) = cU_2; \tag{42}$$

if in this equation we substitute differential coefficients with respect to t for the accented letters U_2^1, U_3^1, U_1^1, and integrate we shall obtain the equation

$$U_3 = U_1\left(\frac{1}{3}\int\left\{\frac{d\log U_1}{dt}2\left(\frac{\left(\frac{dU_2}{dt}\right)^2}{\left(\frac{dU_1}{dt}\right)^2} - \frac{U_2^2}{U_1^2}\right) + cU_2\right\}dt + r_2\right). \quad (43)$$

We may write

$$2\left(\frac{\left(\frac{dU_2}{dt}\right)^2}{\left(\frac{dU_1}{dt}\right)^2} - \frac{U_2^2}{U_1^2}\right) \text{ in the form } 2\left(\frac{\frac{dU_2}{dt}}{\frac{dU_1}{dt}} - \frac{U_2}{U_1}\right)\left(\frac{\frac{dU_2}{dt}}{\frac{dU_1}{dt}} + \frac{U_2}{U_1}\right);$$

by means of (39) and (41) this may be put in the form

$$(cU_1 - b)(cU_1 - b\log U_1 + 2r_2 + \frac{cU_1 - b}{2};$$

hence equations (43) may be transformed into

$$U_3 = U_1\left\{\frac{1}{3}\int\left\{\left(\frac{cU_1 - b\log U_1}{2} + r_2\right)(3cU_1 - 2b) + \frac{(cU_1 - b)^2}{2}\right\}\frac{dU_1}{U_1} + r_2\right\}.$$

Hence U_3 has been transformed into an integrable function of U_1; by a continuation of the process U_4, U_5, &c., may be obtained as functions of U_1, and the method seems generally applicable; for if we equate the coefficient of x^{n+1} in the expansion of

$$\log\frac{d^2p}{dxdt} - \log\frac{dp}{dx},$$

with the coefficient of the same power in the expansion

$$cU_0 + (cU_1 - b)x + cU_2x^2 + cU_3x^3 + cU_4x^4 + \&c.,$$

we shall obtain an equation which may be put in the form,

$$(n+2)\left(\frac{U^1_{n+2}}{U_1^1} - \frac{U_{n+2}}{U_1}\right) + \text{function of}$$
$$(U^1_{n+1}, U^1_n, \ldots U_2^1, U_1^1; U_{n+1}, U, \ldots U_2, U_1) = cU_{n+1};$$

this equation may for brevity be written

$$\frac{U'_{n+2}}{U_1^{n+2}} - \frac{U_{n+2}}{U_1} = \frac{F_{n+2}}{n+2}; \qquad (44)$$

F_{n+2} denoting cU_{n+1} function of

$$(U'_{n+1}, U'_n \ldots U'_2, U'_1; U_{n+1}, U_n \ldots U_2, U_1).$$

Integrating (44) we obtain

$$U_{n+2} = U_1\left(\int \frac{d\log U_1}{dt} \cdot \frac{F_{n+2}}{n+2} dt + r_{n+2}\right), \qquad (45)$$

r_{n+2} being some arbitrary constant. Hence U_{n+2} has been obtained in terms with smaller suffixes, and these in their turn will have been obtained in terms with suffixes still smaller; so that finally U_{n+2} will be obtained as a complex function of U_1.

Now give to n the values of 0, 1, 2, 3, &c. in succession, and substitute the expressions so obtained for U_2, U_3, &c. in the expansion $p = U_0 + U_1 x + U_2 x^2 + \&c.$; then we obtain

$$p = U_0 + U_1\left\{x + x^2\left(\int \frac{F_2}{2}\frac{dU_1}{U_1} + r_2\right) + x^3\left(\int \frac{F_3}{3}\frac{dU_1}{U_1} + r_3\right)\right.$$
$$\left. + x^4\left(\int \frac{F_4}{4}\frac{dU_1}{U_1} + r_4\right) + x^5\left(\int \frac{F_5}{5}\frac{dU_1}{U_1} + r_5\right) + \&c.\right\}. \qquad (46)$$

Now by equation (37) U_1 is a known function of U_0 for

$$U_1 = r_1 e^{-\phi(t)};$$

$\phi(t)$ standing for

$$a\int e^{\alpha t} dt;$$

if we substitute for U_1 its value in U_n the undetermined quantities in (46) will be this letter, and the letters r_1, r_2, r_3, &c.; the values to be assigned will depend upon the initial condition of cylinder with respect to the distribution of the body A, but it was supposed to be initially uniformly distributed, so that at time $t=0$ we have

$$p = \frac{P}{L^{n_1}}$$

also when x vanishes p also vanishes; making x and p each 0 in (46), we obtain 0 for the value of U_0 hence we have

$$a\int \varepsilon^{cv_0}\,dt = at, \qquad (47)$$

and for U_1 we have the value $r_1\,\varepsilon^{-at}$; by substitution in (46) we obtain

$$p = r_1\varepsilon^{-at}\left\{x - a\left\{x_2\left(\int\frac{F_2}{2}dt - r_2\right)\right.\right.$$
$$\left.\left. + x^3\left(\int\frac{F_3}{3}dt - r_3\right) + x^4\left(\int\frac{F_4}{4}dt - r_4\right) + \&c.\right\}\right\}$$

The values of r_1, r_2, r_3, &c., are to be determined as follows: let the integration with respect to t be effected, and then in the last expression make $t=0$; then if we substitute for p its initial value we shall have

$$\frac{P}{L}x = r_1x,$$

and the coefficients of the remaining powers of x take the value o; hence r_2, r_3, &c., will be the values of the integrals

$$\int\frac{F_2}{2}dt, \quad \int\frac{F_3}{3}dt, \text{ &c.}$$

when t has the value 0. Finally we obtain as a solution of (15)

$$p = \frac{P}{L}\varepsilon^{-at}\left(x - \frac{ax^2}{2}\int_o^t F_2dt - \frac{ax^3}{3}\int_o^t F_3dt - \frac{ax^4}{4}\int_o^t F_4dt - \&c.\right).$$

I shall now consider some particular cases, depending upon special values given to the letters a, b, c.

In the first case, consider a to have the value 0; putting this value in the last equation we obtain,

$$p = \frac{P}{L}x.$$

The relation, $a=0$, implies the relation, $\mu=0$; in this case the body A absorbs no light; as B is supposed to be formed by the light absorbed by A, in this case it is plain that no B will be produced, and that the distribution of A through the cylinder will be the same at all time, as it was initially; in this particular problem it was considered

to be uniformly distributed. A similar result might have been obtained from a consideration of the differential equation, for if we make $a=0$ in (15), we obtain the result,

$$\frac{d^2p}{dxdt}=0, \tag{48}$$

of which the integral is

$$p=\phi(t)+\psi(x); \tag{49}$$

if we now apply the conditions $p=o$, when $x=o$, and

$$p=\frac{P}{L}x$$

initially, we find 0 for the value of $\phi(t)$, and

$$\frac{P}{L}x$$

for the value of $\psi(x)$.

The next case that I shall consider, is when $b=0$; and first it may be remarked that this condition implies $m=0$, and therefore implies that the body A by the absorption of light is converted into a body B which is perfectly transparent. We are, as far as I am aware, acquainted with no form of matter which is perfectly transparent, so that the investigation might not be strictly applicable to actual experience, but it is well known that the action of light on many organic colours is of such a nature as to discharge the colour; to such cases the present investigation will apply approximately; making $b=0$ in (15) we obtain

$$\frac{d^2p}{dxdt}=-ae^{px}\frac{dp}{dx}. \tag{50}$$

Integrating with respect t x and adding an arbitrary function of t, we obtain

$$\frac{dp}{dt}=-\frac{a}{c}e^{px}+\phi(t);$$

to integrate a second time, substitute U for e^{px}; also since when $m=0$, c takes the value $-\mu$, let this value be used, then we obtain

$$\frac{1}{U^2}\frac{dU}{dt} = -a - \frac{\phi(t)}{U};$$

the integral of this equation is

$$U = \frac{\varepsilon^{-\int \phi(t)dt}}{a\int \varepsilon^{-\int \phi(t)dt}dt + f(x)}; \qquad (51)$$

the arbitrary functions $\phi(t)$ and $f(x)$ may be so chosen as to satisfy given conditions; suppose that when $x=0$, $p=0$, in (51), substitute e^{px} for U and then give these values to x and p, we shall obtain

$$a\int e^{-\int \mu\phi(t)dt}dt + f(0) = e^{-\int \mu\phi(t)dt};$$

differentiating and dividing by

$$e^{-\int \mu\phi(t)dt},$$

we find

$$-\mu\phi(t) = a$$

by substitution, from (51) we shall obtain

$$e^{-\mu p} = \frac{e^{at}}{e^{at} + f(x)}; \qquad (52)$$

to determine $f(x)$, suppose that the body A was initially uniformly distributed through the cylinder, giving to p the value

$$\frac{P}{L^2},$$

and to t the value 0, from (52) we shall obtain

$$f(x) = e^{\mu\frac{P}{L^2}x} - 1;$$

substituting in (52) we obtain as the solution of (50)

$$e^{-\mu p} = \frac{e^{at}}{e^{at} - 1 + e^{\mu\frac{P}{L^2}x}} \qquad (53)$$

We may now consider a third special case of (15); in that equation make $c=0$, then we get

$$\frac{d^2p}{dxdt} = -ae^{-bt}\frac{dp}{dx}; \qquad (54)$$

this equation may be written in the form

$$\frac{d}{dt}\log\frac{dp}{dx} = -ae^{-bx};$$

integrating with respect to t, and adding an arbitrary function of x we get

$$\log\frac{dp}{dx} = -ae^{-bx}t + f(x),$$

which may also be put in the equivalent form

$$\frac{dp}{dx} = \mathrm{F}(x)e^{-ate^{-bx}};$$

integrating with respect to x and adding an arbitrary function of t we obtain

$$p = \int \mathrm{F}(x)e^{-ate^{-bx}}dx + \phi(t); \qquad (55)$$

if, as in other cases, we suppose that $p=0$, when $x=0$, and that when $t=0$

$$p = \frac{\mathrm{P}}{\mathrm{L}}x,$$

we may determine the arbitrary functions $\mathrm{F}(x)$ and $\phi(t)$; from the last condition, we obtain from (55)

$$\frac{\mathrm{P}}{\mathrm{L}}x = \int \mathrm{F}(x)dx + \phi(0);$$

from this equation we derive by differentiation,

$$\mathrm{F}(x) = \frac{\mathrm{P}}{\mathrm{L}},$$

from the condition $p=0$, when $x=0$, it follows that $\phi(t)$ is the value which the quantity under the integral sign would have if the integration were effected and 0 substituted for x, hence the solution of (54) will be

$$p = \frac{\mathrm{P}}{\mathrm{L}}\int_0^x \epsilon^{-ate^{-bx}}dx; \qquad (56)$$

if the quantity of A in the whole length of the cylinder is required, the limits of the integration will be 0 and L. The

condition $c=0$ implies the condition $mn=\mu$, and therefore $\epsilon^{-\mu}=\epsilon^{-mn}$; consequently, if we have a cylinder containing in solution a body A of which the coefficient of transmission is $\epsilon^{-\mu}$ and this body is converted into a body B, so that each unit of A furnishes n units of B of which the coefficient of transmission is ϵ^{-m}, then if $mn=\mu$ there will be no visible evidence of any structural change, the intensity of the transmitted light depending on the length of the absorbing column, but being independent of the time. This may be merely a mathematical refinement, but in the present state of our knowledge respecting the intimate constitution of material combinations, I do not think that we should be justified in saying that no internal change has taken place, because none is visible.

Another variety of the problem which is the subject of this paper arises from the following consideration; suppose the change from A to B to be so slow, and the contents of the cylinder kept in such a state of brisk agitation, that the absorbing medium may be considered homogeneous, what will be the intensity of light at any time. In this case, p and q being at any time the quantities of A and B coexistent in in the entire length of the cylinder, the intensity of the emergent light at the same time will be given by the equation

$$I=I_o\epsilon^{-\mu p-mq};$$

therefore the loss of intensity will be

$$I_o(1-\epsilon^{-\mu p-mq});$$

at the end of the short interval δt the intensity of the emergent light will be

$$I_o(\epsilon^{-\mu(p+\delta p)-m(q+\delta q)},$$

and the loss of intensity at that time,

$$I_o(1-\epsilon^{-\mu(p+\delta p)-m(q+\delta q)});$$

if the body B only were in solution, the loss of intensity

at time t, would be

$$I_o(1-\epsilon^{-mq})$$

and at time $t+\delta t$,

$$I_o(1-\epsilon^{-m(q+\delta q)});$$

hence the loss due to the presence of A will be at time t,

$$I_o\epsilon^{-mq}(1-\epsilon^{-\mu p}),$$

and at time $t+\delta t$

$$I_o\epsilon^{-m(q+\delta q)}(1-\epsilon^{-\mu(p+\delta p)});$$

hence the quantity of light absorbed by A during the short interval δt will lie between

$$kI_o\epsilon^{-mq}(1-\epsilon^{-\mu p})\delta t, \text{ and } kI_o\epsilon^{-m(q+\delta q)}(1-\epsilon^{-\mu(p+\delta p)})\delta t;$$

hence, since δq the quantity of B formed is supposed to be proportional to the quantity of light absorbed by A during the short interval δt, we shall have

$$\begin{aligned}\delta q &< hkI_o\epsilon^{-mq}(1-\epsilon^{-\mu p})\delta t\\ &> hkI_o\epsilon^{-m(q+\delta q)}(1-\epsilon^{-\mu(p+\delta p)})\delta t.\end{aligned}$$

The lower of these expressions may be written in the form

$$hkI_o\epsilon^{-mq}(1-\epsilon^{-\mu p})\delta t+R,$$

where R denotes a sum of products and powers of small quantities of the second and higher orders; hence ultimately we obtain

$$\frac{dq}{dt}=khI_o\epsilon^{-mq}(1-\epsilon^{-\mu p}); \qquad (57)$$

in this equation the letter h denotes some constant; we may now substitute

$$\frac{dp}{dt} \text{ for } \frac{dq}{dt}$$

by differentiating the equation $\dot{q}=n(P-p)$; hence we obtain by eliminating q, an equation of the following form

$$\frac{dp}{dt}=-a(\epsilon^{bp}-\epsilon^{cp}), \qquad (58)$$

wherein, for brevity, a has been written for

$$\frac{kpI_o\epsilon^{-mnP}}{n},$$

b for mn, and c for $mn-\mu$. Since P, the value of p at time $t=0$ is supposed to be known, if p be expanded in powers of t by Taylor's theorem, it will be easy by means of (58) to obtain the coefficients of the successive powers of t; the following is the expansion as far as the fourth power

$$p = \mathrm{P} - a(\epsilon^{b\mathrm{P}} - \epsilon^{c\mathrm{P}})t + a^2(\epsilon^{b\mathrm{P}} - \epsilon^{c\mathrm{P}})(b\epsilon^{b\mathrm{P}} - c\epsilon^{c\mathrm{P}})\frac{t^2}{2}$$

$$- a^3\Big((b^2\epsilon^{b\mathrm{P}} - c^2\epsilon^{c\mathrm{P}})(\epsilon^{b\mathrm{P}} - \epsilon^{c\mathrm{P}})^2 + (b\epsilon^{b\mathrm{P}} - c\epsilon^{c\mathrm{P}})^2(\epsilon^{b\mathrm{P}} - \epsilon^{c\mathrm{P}})\Big)\frac{t^3}{\underline{3}}$$

$$+ a^4(\epsilon^{b\mathrm{P}} - \epsilon^{c\mathrm{P}})\Big\{(\epsilon^{b\mathrm{P}} - \epsilon^{c\mathrm{P}})^2(b^2\epsilon^{b\mathrm{P}} - c^2\epsilon^{c\mathrm{P}})$$

$$+ 4(\epsilon^{b\mathrm{P}} - \epsilon^{c\mathrm{P}})(b^2\epsilon^{b\mathrm{P}} - \epsilon^2\epsilon^{c\mathrm{P}})(b\epsilon^{b\mathrm{P}} - c\epsilon^{c\mathrm{P}}) + b\epsilon^{b\mathrm{P}} - c\epsilon^{c\mathrm{P}}\Big\}\frac{t^4}{\underline{|4}} + \&c.$$

As in previous examples particular values may be assigned to the three parameters a, b, c, giving rise to distinct solutions of (58). Suppose that the action of light on the body A is of such a nature as to discharge the colour and convert it into a perfectly colourless medium, in such a case

$$m = 0,\ a = \frac{khI_o}{n},\ b = 0,\ c = -\mu,$$

and equation (58) may be written in the form

$$\frac{dp}{dt} = -a(1 - \epsilon^{-\mu p}), \qquad (59)$$

of which the integral is

$$\epsilon^{\mu p} = 1 + C\epsilon^{-\mu at},$$

or if the constant C be determined by the conditions $p = \mathrm{P}$ when $t = 0$, we may write it in the form

$$\epsilon^{\mu p} = 1 + (\epsilon^{\mu \mathrm{P}} - 1)\epsilon^{-\mu at}.$$

Another variety of the problem will be as follows: suppose the solution of A to be perfectly transparent for the kind of light under consideration, then μ will have the value 0, and the letters b and c in (58) will have the same value mn, hence (58) will now have to be written

$$\frac{dp}{dt} = 0,$$

whence we have p = constant; a result which is in agreement with the hypothesis that B is formed from A by the absorption of light, for if no light is absorbed no change will take place in the contents of the cylinder.

If the conversion from A to B is attended with no visible change, then $c = 0$, and (58) may be put in the form

$$\frac{dp}{dt} = -a(\epsilon^{\mu p} - 1);$$

of which the integral is

$$1 - \epsilon^{-\mu p} = C\epsilon^{-\mu a t};$$

if the value of the constant c be determined by the conditions $t = 0, p = P$, we may put the last equation in the form

$$\epsilon^{\mu a t} = \frac{1 - \epsilon^{-\mu P}}{1 - \epsilon^{-\mu p}}.$$

Throughout this investigation it has been considered sufficient to proceed only so far as to determine p; for the value of q may then be deduced by (2) or by (7); then these values of p and q substituted in the equation

$$I = I_0 \epsilon^{-\mu p - mq},$$

will give the intensity of the light transmitted at any instant through any section of the cylinder.

If the light be not homogeneous, or if the absorption be not the same for every species, in place of the last equation we must use the equation

$$\Sigma I = \Sigma I_0 \epsilon^{-\mu p - mq}.$$

In this case the letters μ and m will have different values for rays of different wave length. Objection may be raised to those results in this paper which postulate the existence of perfectly transparent media, on the ground that no such medium has yet been discovered; in reply, it may be stated that in this, as in other branches of science, a limitation of

the conditions under which the investigation is conducted, leads to a clearer perception of the problem to be solved. For instance, in the theory of heat the imaginary engine of Carnot, which involves conditions incompatible with our received notions of matter has nevertheless assisted in the development and definite expression of an important law in thermodynamics. Also, if mathematicians had waited for the discovery of a perfectly rigid solid, we should not yet have any treatises on statics and dynamics. Also, in the profound treatise of Fourier on heat, the solids considered involve conditions of conductivity and specific heat not exactly fulfilled by physical solids.

The subject of this paper manifestly admits of several practical applications; for instance, the quantitative determination of colouring matter undergoing change, in cases where the balance could not be used, on account of the minute quantity of the body to be estimated, or on account of its instability. It may also be applied to the determination of quantities and intensities of light.

[*Mathematical and Physical Section.*]

10th December, 1890.

JAMES BOTTOMLEY, B.A., D.Sc., F.C.S., President of the Section, in the Chair.

Dr. BOTTOMLEY gave the following differential equation arising from the consideration of a problem relative to the absorption of light:—

$$\frac{d^2p}{dxdt} = -ae^{pc-bx}\frac{dp}{dx}.$$

Ordinary Meeting, December 30th, 1890.

JAMES BOTTOMLEY, B.A., D.Sc., F.C.S., Vice-President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Mr. J. COSMO MELVILL, M.A., F.L.S., read a paper entitled: "Description of *Drosera intermedia* (Hayne) *forma subcaulescens*, with remarks on the geographical distribution of the family."

A paper on "A New Symbolic Treatment of the Old Logic," by Mr. JOSEPH JOHN MURPHY, communicated by the Rev. ROBERT HARLEY, F.R.S., F.R.A.S., was read by Dr. J F. W. TATHAM.

Ordinary Meeting, January 13th, 1891.

JAMES BOTTOMLEY, B.A., D.Sc., F.C.S., Vice-President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Reference was made to the death of Mr. GEORGE WARING ORMEROD, who was elected a member of the Society in 1841, succeeded Sir BENJAMIN HEYWOOD as treasurer, and continued in connection with the Society until he removed from the district. Mr. DE RANCE pointed out that Mr. ORMEROD published the first detailed account of the Cheshire salt district in 1847, and continued to take an active interest in geological work up to his death.

A discussion on Lancashire and Cheshire boulders ensued, in the course of which the formation of a boulder committee to record the localities and other characteristics of the boulders of the district was suggested.

Mr. DE RANCE then read the second part of the detailed account by himself and Mr. WILLIAM BROCKBANK of the geological section exposed in the Levenshulme and Fallowfield railway cutting.

Mr. W. H. GEE, B.Sc., F.C.S., read a paper by himself and Mr. ARTHUR HARDEN, M.Sc., Ph.D., on two new instruments for ascertaining the volumes of bodies.

[*Microscopical and Natural History Section.*]

Ordinary Meeting, January 19th, 1891.

ALEX. HODGKINSON, M.B., B.Sc., President of the section, in the Chair.

Mr. J. COSMO MELVILL exhibited four land shells of great curiosity, interest, and beauty, recently described, all from the Old world, viz. :—

Diaphora Moellendorfiana (Hidalgo) from Cebu I.

Helix retisculpta (v Mart.) from Ussal, Damaraland.

Opisthostoma grandispinosum (Godwin-Austen), from Borneo.

Cyathopoma aries (v Moellendorf) from Cebu I. Phillipines.

There were also exhibited by the PRESIDENT the remarkable fungus on the caterpillar of the New Zealand Swift moth, which is eaten by the Maoris; and by Mr. SCOWCROFT, a number of flowers dried by a new method so as to preserve their form and colour.

Ordinary Meeting, January 27th, 1891.

JAMES BOTTOMLEY, B.A., D.Sc., F.C.S., Vice-President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

A letter from Professor SYLVANUS THOMPSON, stating that he was engaged in writing a memoir of William Sturgeon, the electrician and former member of the Society, and asking for any information concerning him in the Society's possession, was read. A conversation ensued, during which Mr. Alderman BAILEY stated that he believed that the Salford Corporation had some material relating to the life and work of Sturgeon in its possession.

Mr. Alderman BAILEY exhibited specimens of artificial flowers which his son had brought home from the Canary Islands. The flowers exhibited were very beautiful, representing myrtle, fuchsia, and other natural flowers, and were made of fish scales, feathers, and silver wire. Alderman BAILEY regretted the want of house industries in this country, and suggested that in many ways such industries might be lucrative. A discussion on the possibilities as regards the revival and extension of handicraft industries ensued.

Ordinary Meeting, February 10th, 1891.

JAMES BOTTOMLEY, B.A., D.Sc., F.C.S., Vice-President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Mr. C. E. DE RANCE, F.G.S., called attention to some deep borings recently made through the keuper marls, in which the cores were remarkably variegated, in some instances being divided by a layer of gypsum, the marls being green on one side of the gypsum and red on the other. It was suggested that on one side of the gypsum the iron had been dissolved out and carried away, leaving the colour green, while the gypsum prevented the same action on the other side. The formation of the gypsum in this and other cases was discussed by Mr. W. BROCKBANK, Mr. P. F. KENDALL, and Mr. H. GRIMSHAW.

Mr. FARADAY called attention to the fact that an opinion expressed in a paper read before the Society early in 1884, that the phenomena of protective vaccination and non-recurrent disease must be interpreted as due to a vaccine educational influence, developing resisting vigour in the living cells of the body attacked, is now the apparently accepted doctrine, in preference to the old idea of the invading microbe using up some material only rarely elaborated.

Mr. PERCY F. KENDALL read a paper "On the source of some remarkable boulders in the Isle of Man," and exhibited specimens of a peculiar blue hornblende rock, found scattered as travelled blocks all over the Isle of Man, and identified by him with the rock of Ailsa Craig.

Hymenopterological Notices. By P. Cameron.

(*Received February 11th, 1891.*)

I. *On some Hymenoptera parasitic in Indian injurious insects.*

For the examination of the insects here noticed and described, I am indebted to Mr. E. C. Cotes, of the Indian Museum, whose good work in connection with Indian Economic Entomology is well known and appreciated. All the new species described are small, if not minute; and one of them, *Aphelinus theæ*, is a very remarkable little insect.

PLATYGASTER ORYZÆ, *sp. nov.* (Pl. I. f. 7 & 7*a*).

Brownish, shining, impunctate; the legs pallid yellow; the antennæ yellow; wings hyaline; mesonotum with a large, somewhat roundish, fovea in the middle near the scutellum, which is convex and rounded at the apex [this fovea is present in two examples, and may be accidental]; abdomen subpetiolate, as long as the head and thorax united, the base of abdomen apparently not striolate ♀.

Length barely 1 mm.

Foerster divides the sub-family *Platygasterina* into 21 "genera," Thomson into 11. I cannot make the present species fit into any of the divisions, and therefore place it in *Platygaster*, *sensu lat.* The "generic" characters are as follows: Antennæ with the 4-jointed club in ♀ subabrupt, the club joints longer than the others; the last joint conical, nearly twice the length of the penultimate, the other club

joints somewhat moniliform. Abdomen subpetiolate. Parapsidal furrows obsolete. Scutellum convex, rounded at the apex, glabrous. Ocelli almost forming a triangle, wings without nervures, deeply fringed. Tarsi 5-jointed. Vertex immarginate.

Bred from *Cecidomyia oryzæ*, Wood-Mason, a midge which proved destructive to paddy in Moughyr in October, 1880. See *Notes on Indian Economic Entomology*, No. 2, p. 103, pl. vi. f. 6.

The species of *Platygaster* greatly affect species of *Cecidomyia*, most of which are gall markers.

APHELINUS THEÆ, *sp. nov.* (Pl. I. f. 5 & 5*a*).

Yellow; the legs pallid, with apex of the hinder tibiæ and tarsal joints infuscated. Head dilated behind the eyes. The second antennal joint small; the third large, thicker than the second or fourth; the fourth and fifth not half the size of the third, and equal in length; the club abrupt, longer than the preceding four joints united; the last joint conical, apparently thinner than the penultimate. Hinder tarsal spur as long as the metatarsus. Wings with a long hair fringe.

Length not ½ millim.

The only specimen I have seen is mounted in balsam and has got flattened, so that its exact shape cannot be seen satisfactorily. Apparently there are two broad triangular processes projecting from the thorax to near the middle of the abdomen; but their precise relationship or structure cannot be correctly made out. They seem to proceed from the base of the mesonotum. The sutures of the thorax cannot be observed. I am not aware of any similar structure being known in the family. It is so peculiar that I have no doubt that it will be proved, on further examination, from fresh specimens, of generic value—that the species forms the

type of a new genus. Otherwise the species compares fairly well with *Aphelinus*.

Bred from the tea scale insect *Aspidiotus theæ* from Janygo, where it was bred by Mr. F. W. H. Mills. The group of *Aphelininæ* are parasitic in those destructive pests, the *Coccidæ*.

PTEROMALUS ORYZÆ, *sp. nov.* (Pl. I. f. 2 & 2*a*).

Coppery-green, the scape and legs yellow, the femora with a more testaceous tinge; the mandibles rufo-testaceous. Head and thorax closely, and somewhat strongly, punctured; the antennal groove transversely striated; the mesopleuræ more strongly punctured than the mesonotum; the metapleuræ shining, impunctate; median segment finely punctured, except at the apex, and with a stout keel down the centre. Abdomen shining, as long as the thorax; the apical segment conical. Wings hyaline, with a very faint fulvous tinge; the nervures yellowish. In some examples the femora are infuscated; the coxæ punctured, green; the flagellum of the antennæ may be blackish to testaceous.

Length nearly 3 mm.

This species belongs to the sub-tribe *Pteromalides* of Thomson (Hymenoptera Scandinavia, IV.); but to what particular genus, as defined either by the learned Swede or to the more numerous genera of Foerster, it passes my wit to determine; and in this my valued correspondent, Prof. G. L. Mayr, of Vienna, agrees with me. I have, therefore, referred it to the old genus *Pteromalus*. The ringlet is 2-jointed; the succeeding joint is as long as it united; the club is 3-jointed (but the joints can only be with difficulty seen); the antennæ have thus 13 joints. The parapsidal furrows are obsolete.

A parasite on the destructive rice weevil *Calandra*

oryzæ. Cf. *A preliminary account of the wheat and rice weevil in India*, by E. C. Cotes, p. 5.

COTESIA, *gen. nov.*

Antennæ 17-jointed, the third joint longer than the fourth. First abscissa of radius is longer than the thickness of the stigma, originating somewhat beyond the middle; the other abscissæ obsolete. First abscissa of the cubitus originating from the transverse præbrachial, and becoming obsolete beyond the curved transverse first cubital nervure; the other and anal nervures obsolete. The recurrent nervure received before the middle of the cellule. Axillary nervure not divided. Radius and cubitus in hind wings obsolete. Parapsidal furrows obsolete. Abdomen curved; ventre convex; ovipositor curved.

Apparently comes nearest to *Pygostolus*; but differs in having the antennæ 17-jointed; in having no radius, and only one cubital cellule.

COTESIA FLAVIPES, *sp. nov.* (Pl. I. f. 3 & 3*a*).

Black, shining; the antennæ for the greater part testaceous beneath; the legs yellow, the ventral surface and sides yellowish-testaceous; the ovipositor short, black. Thorax covered with a whitish pubescence; wings hyaline, the nervures fuscous; stigma large. Head well developed behind; the base of abdomen piceous-black; the abdomen shorter than the thorax, the segments edged with yellow. Median segment aciculate. The antennæ longer than the body.

Length 2¼ mm.

A parasite of the moth, whose larva proved injurious to *Gorghum vulgare* at Poona. See *Indian Museum Notes*, No. 1.

Mr. Cotes sends two species of *Pimpla*.

1. PIMPLA PUNCTATOR, Linn, *Syst. Nat.*, *t.* i., p. 935–38; Vollenhoven, *Stett. Ent. Zeit.*, 1879, p. 143 = *P. pedator*, Fab., *Syst. Piez.*, p. 114–6.

Vollenhoven, *l.c.*, records the rearing of this ichneumen from *Papilio Pammon*; and says further, "Wahrscheinlich kommt *Punctator* parasitisch in verschiedenen Insecten vor." The specimens sent by Mr Cotes were bred from the caterpillars of *Cricula trifenestrata* in Hazanbugh. The parasite has a very wide distribution, being found widely distributed in the Oriental region and in Celebes.

2. PIMPLA ZEBRA, Vollenhoven, *Stett. Ent. Zeit.*, 1879. p. 147. This has also been bred from *Cricula trifenestrata*. Vollenhoven describes it from Java.

II. *Two New Species of* EUCHARINÆ.

The group of *Eucharinæ* is one of the most remarkable in the family *Chalcididæ*. Not only are they much larger than usual, but they are remarkable for the extraordinary development of the thorax, the scutellum especially showing many curious developments. Until recently the history of these interesting insects was quite unknown. We now, however, are acquainted with the habits of two species from widely remote regions; and, as the various groups of *Chalcididæ* confine themselves, with remarkable uniformity, in their attacks to the same class of insects, I think that we are justified in concluding that their prey is the ant tribe. The discoverer of this interesting fact is Prof. Forel, of Zurich, who, receiving some cocoons of the huge Australian "Bull-dog" Ant *Myrmecia forficata*, Fab., from Bull Creek, South Australia, had the curiosity to open some of them and found a ♂ and ♀ of the species I have called *Eucharis myrmiciæ* in two of them, and in a perfect condition, except that their wings had not yet developed.

So far as I am aware only one other Hymenopterous

insect is parasitic on ants, this being the European Braconid *Elasmosoma berolinense.*

EUCHARIS MYRMICIÆ, *sp. nov.* (Pl. I. f. 10 *a—c*).

Cuprea; scapo antennarum, pedibus abdomineque rufo-ferrugineis; flagello antennarum nigro; apice scutelli inciso.

Long. fere 10 millim.

Hab. Bull Creek, South Australia.

Occiput margined above, slightly concave; ocelli in a straight line; front broadly excavated; clypeus transverse at the apex. Head coarsely transversely striolated; the front with the striæ much more widely apart and more regular; clypeus impunctate, smooth and shining; convex, and broadly furrowed along the sides. Mandibles long, curved, and without teeth and testaceous. Antennæ not much longer than the thorax, not much thickened towards the apex; the third joint distinctly longer than the fourth, the others becoming gradually shorter and very slightly thicker; in ♂ as long as the body, tapering towards the apex; densely micropilose. Thorax coarsely rugosely punctured, the space outside the parapsidal furrows more finely than the central portion. Parapsidal furrows diverging in front; a broad furrow runs from them to the tegulæ; there is a depression in the centre at the base of the scutellum which is coarsely rugosely reticulated; the apex projecting into a lamina with a curved incision in the centre; in the ♀ it does not form a lamina and is more deeply curved; and in the ♂ there is, in the centre, a stout keel which is not so conspicuous in the ♀. Pro- and mesopleuræ in front coarsely rugosely reticulated, the rest of the mesopleuræ finely rugosely punctured; metapleuræ rugosely reticulated. Petiole oblique; in ♀ shorter, in ♂ longer than hind femora; dark coppery-green with varying tints; the legs and abdomen, except at the base, rufo-testaceous; petiole coppery; antennæ black; wings apparently hyaline.

CHALCURA BEDELI, *sp. nov.* Cam. (Pl. I. f. 8, 9, *a*—*b*).

Dark blue; the antennæ black, dark testaceous at the apex beneath, the legs testaceous, the coxæ, the base of anterior femora, the middle more broadly at the base and the posterior to near the apex, black; abdomen piceous, the base and apex of the second, and the others broadly blackish; wings hyaline, a light fulvous cloud in the middle, and which becomes cleft before the base of the humerus; the upper branch running along the ulna; the lower along the lower edge of the wing; the nervures testaceous. Antennæ about as long as the thorax, serrate; the joints of the flagellum (except the last) sharply produced in front; the basal joints with the apices very sharp; the first joint of the flagellum nearly twice the length of the second. Head shining, the front broadly depressed; the vertex and clypeus transversly; the front obliquely striolated. Thorax shining, irregularly striolate; except a large space on the lateral lobe of the mesonotum in front of the tegulæ. Parapsidal furrows distinct; and there is an indistinct furrow between them. The middle of mesopleuræ excavated transversely; the metapleuræ obliquely. There is a transverse narrow furrow in front of the scutellum; its base is hollowed, the hollow with stout longitudinal keels; the scutellum finely longitudinally striolated; the apex produced obliquely; the apex scarcely truncated; the median segment aciculate. Petiole a little more than twice longer than broad.

The ♂ has the antennæ flabellate; the branches curved; the penultimate joint has the branch much shorter than the others; the last joint does not carry a branch, and is sharply produced at top and bottom. The thorax is more strongly striolate than in the ♀; the depression at the base of the scutellum is obsolete, and the apex of the scutellum is more deeply incised; the median segment is irregularly reticulated,

and bears two keels down the centre. The petiole is more than twice the length of the female's, being not much shorter than the rest of the abdomen; irregularly aciculate at the base. The wings are entirely hyaline, and want the forked cloud found in the ♀.

This species belongs to Kirby's genus *Chalcura* (*Jour. Linn. Soc. Zool.* XX. 30), of which only one species is known, namely, *Eucharis deprivata*, Walker from Ceylon. It differs from the other groups of *Eucharis* with simple apex of scutellum in having the antennæ flabellate in the ♂, except from *Rhipipallus*, which has the antennæ in the ♂ biramose.

Found by the well-known French coleopterist M. L. Bedel, at Edough in Algeria, living in the nests of *Myrmecocystus viaticus*. For the examination of the specimens I am indebted to Prof. E. Emery of Turin, so noted for his studies on ants.

III. *Two New Species of* TELENOMUS *reared from Hemipterous Eggs from the Amazon Valley.*

TELENOMUS MELANOGASTER, *sp. nov.*

Yellowish-testaceous, the vertex and abdomen black, the scape of the antennæ wanting the testaceous hue found on thorax; two fuscous streaks on the mesonotum; wings hyaline with a fuscous tinge; the fringe long; the hinder femora a little infuscated in the middle. Front punctured; mesonotum finely punctured. Ocelli situated quite close to the eyes. Scape elongate, nearly as long as the three following joints united; joints 2—5 elongate, the third and fourth longer than the second and fifth; the sixth and following joints moniliform, not half the length of the fifth; the base of abdomen striolate, sordid testaceous. Parapsidal furrows absent; scutellum subconvex, aciculate. ♂.

Length 1¼ millim.

This, and the following species, belong to Thomson's *Telenomini* and, apparently from its punctured front, to *Telenomus*; the difference between *Telenomus* and *Phanurus* lying in the latter having the front smooth and the ovipositor exserted. I can hardly look upon *Phanurus* as distinct from *Telenomus*.

Bred from the eggs of a bug from the Amazon Valley.

TELENOMUS (PHANURUS) AMAZONICA, *sp. nov.*
(Pl. I. f. 4—4, *a*).

Black, the six basal joints of the antennæ pallid yellow. Head and abdomen shining, impunctate; mesonotum opaque, alutaceous, almost punctured; base of second segment striolate; scutellum shining. Antennæ with a four-jointed abrupt club, its last joint thinner and smaller than the penultimate; the second and third joints sub-equal. Ocelli situated close to the eyes. Second abdominal segment larger than all the others united. Ovipositor exserted. ♀. Length 1½ millim.

Amazon Valley.—Bred from the eggs of a bug.

It is remarkable that most of the species of *Telenomus* whose habits have been investigated are parasites in the eggs of bugs.

IV. *A New Genus of European Tenthredinidæ.*

HENNEDYIA *gen. nov. (Tenthredinidæ.)*

Antennæ filiform, 22-jointed. Fore wings with two radial and four cubital cellules; the second and third of the latter receiving each a recurrent nervure; lanceolate cellule with an oblique cross nervure; hind wings with two cubital cellules. Spurs not reaching to the middle of metatarsus; patellæ obsolete; claws simple.

This genus belongs to the Tribe *Tenthredina* and sub-tribe *Selandriades* of Thomson and of my *Monograph of*

the British Phytophagous Hymenoptera. From any of the described genera of that group it is to be at once recognised by the great number of joints in the antennæ, being six more than in *Phyllotoma* the genus known up till now with the most numerously jointed antennæ, namely, sixteen. *Phyllotoma*, however, has (like all its allies, the leaf-mining Sawflies) only three cubital cellules, while further there are no cubital cellules in the hind wings. In the form of the antennæ undoubtedly it agrees best with *Phyllotoma;* and, in fact, there is no other genus, except *Phyllotoma* with which, as regards the antennæ, it can be compared. In the neuration of the wings and in bodily structure it almost agrees with *Athalia*; but *Athalia* has the antennæ at the outside not more than 10—11 jointed, while further they are sub-clavate in both sexes. On the whole I should consider *Hennedyia* more nearly related to *Athalia* than to *Phyllotoma*; but its relationship can only be finally settled by the discovery of the ♀.

The genus I dedicate to the memory of my first mentor in natural history, Mr. Roger Hennedy, the author of the *Clydesdale Flora.*

HENNEDYIA ANNULITARSIS, *sp. nov.* (Pl. I. f. 1—1*a*.)

Nigra, nitida, pronoto, tigulis abdomine pedibusque rufo-testaceis; apice tibiarum articulisque tarsorum nigris; alis fuscis, nervis nigris. ♂.

Long. fere 5 mm.

Antennæ longer than the body, filiform, tapering towards the apex, almost bare; the basal two joints globose, of almost equal length; the third joint nearly one-fourth longer than the fourth; the other joints becoming gradually shorter to the apex; the third joint slightly curved. Cheeks emarginate, the occiput almost convex; frontal area not clearly defined; a fovea below the ocelli and there is a smaller one immediately above the antennæ. Clypeus convex, a broad and mode-

rately deep furrow at its base; the apex almost transverse. Eyes slightly converging beneath; not reaching to the base of the mandibles. Thorax shining, impunctate; the central and lateral furrows on the mesonotum wide, deep; a narrow, shallow, indistinct furrow on the scutellum. Cenchri clear white; the hollow separating them wide, deep; blotch large, pale. Radial nervure received a little beyond the middle of the third cubital cellule; transverse basal nervure received quite close to the base of the cellule; the first transverse cubital somewhat beyond the basal third; the second at the basal third; the cubital nervures being angled where the recurrent nervures are received. There is a horny point at the apex of the second cubital cellule. The accessory nervure in hind wings received beyond the middle. Legs bearing a white microscopic down: the coxæ, trochanters, apex of tibiæ, more than the apical third of the metatarsus; the apical three-fourths of the second joint, and the whole of the other joints on the hind tarsi (the anterior and middle tarsi with the black less extended) and the base of the fore femora, black.

It will be noticed that the tarsi are annulated with black as in most of the species of *Athalia*.

Taken at Gibraltar by Mr. J. J. Walker, R.N.

V. *A New Indian Species of* RHINOPSIS.

RHINOPSIS CONSTANCEÆ, *sp. nov.* (Pl. I. f. 6).

Black, the mandibles, clypeus, pronotum, the mesothorax, except a line on the sternum, the apex of the mesonotum and its sides before the tegulæ, the median segment, and the antennæ ferruginous; the narrowed basal half of the petiole white; the coxæ beneath, more or less of the trochanters; a broad line on the base of the femora and the tarsi reddish; the base of the tibiæ and the apex of the femora, obscure reddish. Wings hyaline, a broad smoky

band originating at the middle of the stigma; nervures obscure testaceous, paler at the base; the stigma fuscous, pale at the base. Head finely rugosely punctured, semi-opaque. Eyes slightly diverging beneath. Ocelli hardly forming a triangle, the anterior being too far in front, separated by a greater distance from the posterior than these are from each other. The posterior separated from each other by half the distance they are from the eyes. Clypeus convex, keeled in the middle, the apex triangular. Apex of mandibles piceous. Prothorax finely and closely punctured, somewhat convex above, the sides concave, furrowed in the centre, the lower part of the concavity projecting more than the upper, the edge of the latter being furrowed and margined; prosternum furrowed, widely in front, narrowing behind. Mesothorax finely punctured; parapsidal furrows wide, parallel; there is a large shining keeled depression below the tubercles, the pleuræ behind this being convex; mesopleuræ widely furrowed, keeled in the centre. Median segment with a straight central and two lateral curved converging keels in the centre; and, on the edge, are two other keels; the interstices transversely striolate; the apex semiperpendicular, transversely striolate and keeled above.

Rhinopsis ruficornis, Cam. is nearly related to *R. Constanceæ*, but differs in having the hinder ocelli separated from the eyes by more than twice the distance they are from each other; in the mesonotum being without black at the base. in the scutellum being ferruginous; in the pronotum being deeply furrowed in the middle, in the apex of the median segment being tuberculate laterally before the curve; in the lateral central keels being less distinct and more widely apart; in the narrow part of the petiole being longer, the apex nodose; while in *Constanceæ* it becomes gradually developed from the middle; the legs are stouter and have the femora not so attenuate at the apex; the wings are shorter

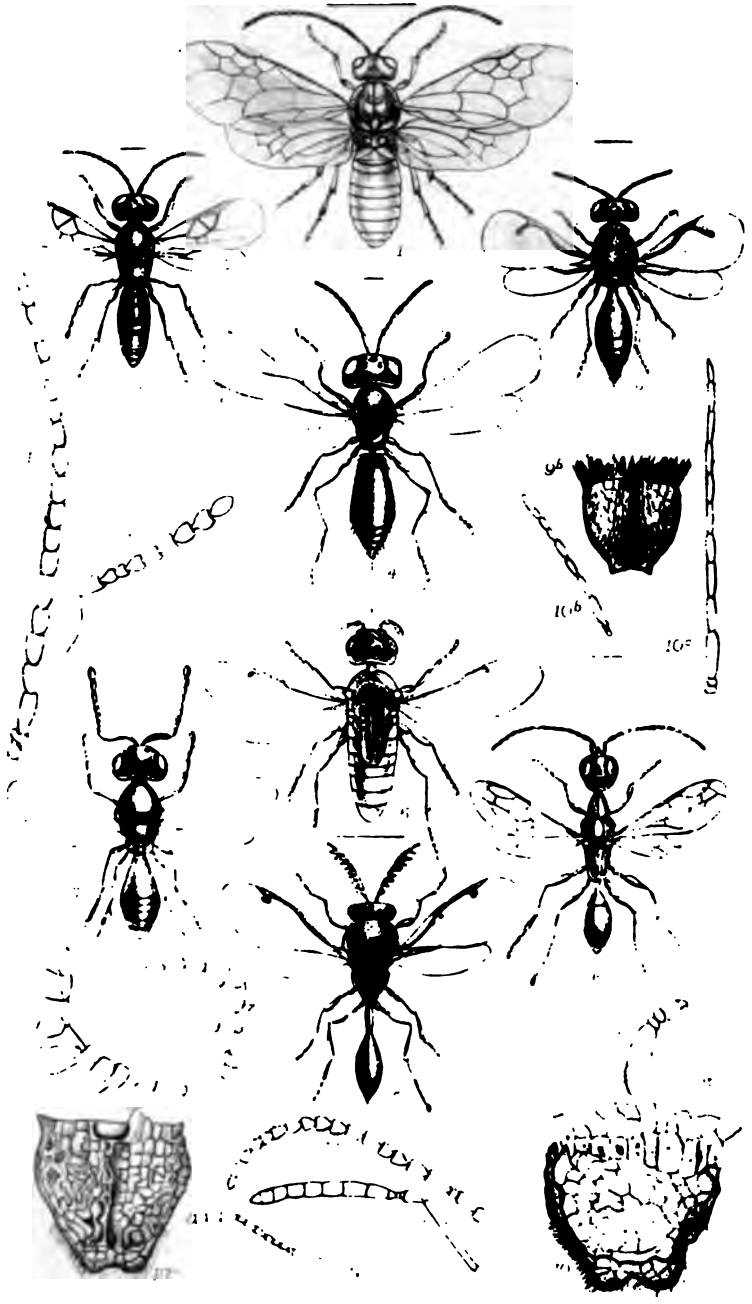
and have the second recurrent nervure interstitial, while in the present species it is received in the basal third of the cellule, the wings further being deeply smoky before the middle.

Hab. Poona (*Wroughton*).

Explanation of Plate.

FIG.

1. *Hennedyia annulitarsis*, 1ª antenna.
2. *Pteromalus oryzæ*, 2ª antenna.
3. *Cotesia flavipes*, 3ª antenna.
4. *Telenomus amazonicus*, 4ª antenna.
5. *Aphelinus theæ*, 5ª antenna.
6. *Rhinopsis Constanceæ*.
7. *Platygaster oryzæ*, 7ª antenna
8. *Chalcura Bedeli* ♂.
9. ,, ,, antenna ♀, 9ª antenna ♂, 9ᵇ scutellum.
10. *Eucharis myrmiciæ*, scutellum ♀, 10ª scutellum, 10ᵇ antenna ♀, 10ᶜ antenna ♂.



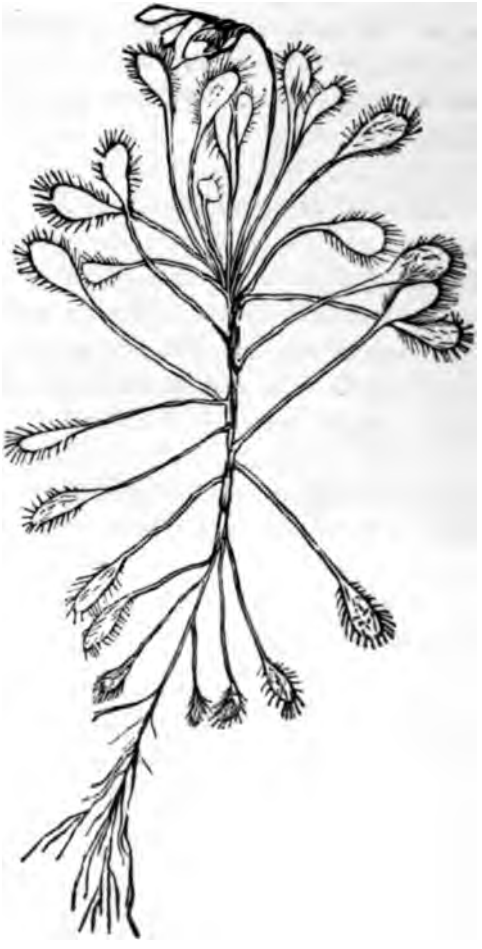
Description of Drosera intermedia (Hayne), forma subcaulescens, with remarks on the Geographical distribution of the family. By James Cosmo Melvill, M.A., F.L.S.

(*Received December 16th, 1890.*)

I have been requested by several botanists to give a more detailed account of this curious state or variety of the long-leaved Sundew of our marshes and moors than has hitherto been afforded. The varietal name was appended, at my instance, to *D. intermedia* in the 8th Edition of the *London Catalogue of British Plants*, published May, 1886, and a few specimens from the original locality where it was first detected have been distributed through the medium of the Botanical Exchange Club, but as yet no proper description has been given of the form.

Drosera subcaulescens differs from the type mainly in having a very decided and leafy stem, varying in height from ½ inch to two inches; in the Cheshire (Wybunbury) specimens the stem is leafy to the base, the leaves, which have long petioles, projecting almost at right angles to the stem, while towards the upper part of the stem, at the point where it emerges from the water, or watery mud in which it has grown, the usual tendency to form a rosette of leaves is noticeable. The specimens when growing were of a pale grass-green colour, differing much in outward appearance from the other *Droseræ* inhabiting the sphagnaceous turbaries in quantities around. It grew plentifully in three or four deep clear water trenches that had some time or other been cut straight across the bog, towards the N.E. corner mainly, and not far from the principal station for *Lastrea cristata*

(Presl), for which Wybunbury is one of the nine localities in this country.



Drosera intermedia (*Hayne*),
forma :—subcaulescens (*Melvill*),
from deep clear peat-ditches, Wybunbury Bog, Cheshire.

It was on July 4th, 1878, in company with Mr. and Mrs. Edward W. Nix, that this was first gathered, and since then it has been noticed in several parts of Great Britain

and Ireland. The leafy stem gives it a curious appearance when growing, and would almost suggest, superficially, a link between the species with leafless scapes, and the truly caulescent, such as *D. peltata* (Sm.) and *D. auriculata* (Backhouse) from Australia.

In the *Phytologist*, New Series, Vol. II. p. 25 sqq., 1857, an account is given by the Rev. Dr. Hind, formerly Rector of Pinner, and now of Honington, Ixworth, Suffolk, of Irish Botany, and amongst interesting plants observed he has given a sketch of what is evidently the identical form now under discussion.

He came across it in a muddy ditch close to the highway, crossing the north shoulder of the "Purple Mountain," Killarney, and mentions these specimens as all being of a faint yellowish green, and not showing any signs of flowering.

Dr. Hind also alludes to the fact that Dr. Hull, in his "British Flora," Vol. I., 1799, seems to have observed and placed on record this caulescent form, saying that he had in some cases found it growing amongst *Sphagnum*, and that the stem occasionally reached two inches, with numerous leaves. He did not notice, nor have subsequent observers, the other two British species assuming this condition.

Upon the publication of these remarks of Dr. Hind, four or five additional localities were soon afforded by various contributors to the *Phytologist*, viz.: New Forest, Hants, by Mr. Pamplin; Lancashire, Mr. John Hardy; Taylor's Hill, Galway, Mr. Kirk, who also gave Tolchmoor, Devon, and Connemara, Ireland.

Dr. Boswell (Syme), *Eng. Bot.*, 3rd Ed., Vol. 2. p. 33, mentions the fact of *D. intermedia* sometimes producing a short leafy stem, with the internodes slightly developed.

The only other specimens I have observed of the same state in American collections were gathered by myself on May 9th, 1872, in pine barren swamps about four miles

N.W. of Wilmington, North Carolina, U.S.A., when I had the satisfaction at the same time of gathering the far more extraordinary member of the same order, the Venus' Fly Trap, *Dionæa muscipula*, (Ell.), for which Wilmington and the neighbourhood of the Santee River in the neighbouring state of South Carolina are the only two known localities.

The Rev. Edward F. Linton has forwarded me this summer specimens from the New Forest; Mr. F. J. Hanbury informs me he has gathered it at Thursley Common, Surrey, June 28th, 1890, and possesses it in the Boswell (Syme) British Herbarium from Woking Common, Surrey, and Tolchmoor Common, Devon, 1850, the latter being very fine specimens. Some of these may more approach the less developed form characterised by F. Schultz as *f. ramosa*, of which I have specimens collected near Berlin, where the stem is simply prolongated, without any cauline leaves.

I am much indebted to Mr. Charles Bailey, F.L.S., for a long list of the British and European *Droseræ* contained in his extensive Herbarium: my own collection also possesses many specimens from widely distant localities. Of our three British (and European) species *D. intermedia* (Hayne) has the widest distribution, extending from Arctic Europe to Western Asia, also from Canada and North America to Brazil; absent, however, according to Nyman, in Lapland and Finland. *D. anglica* (Huds.) is more restricted, being very rare in the south of England, absent from Portugal, probably also not occurring in Spain, Greece, Turkey, etc., and only found, so far as the New World is concerned, in Arctic America.

D. rotundifolia (L.), the most generally diffused species in this country, is found throughout the whole length and breadth of Europe, with the exception of S. Spain, S. Italy, Sicily, Sardinia, Greece, and Turkey; also is abundant in many parts of the Northern United States; in Georgia and Florida, however, *D. capillaris* (Poir.) and *D. brevifolia*

(Pursh) allied species, (the latter, however, with large white flowers and more slender build,) are apt to be mistaken for it. The variety *distachya* (*DC. Prodromus* I. p. 318) with bifid scape, two spiked at apex, is a luxuriant state found occasionally in both countries. *D. obovata* (M. and K.) is evidently a hybrid between *rotundifolia* and *anglica*. I have gathered this in Wybunbury Bog, growing with its probable parents. This Cheshire locality, therefore, may be considered one of the richest in this country for *Drosera*, as all the species and forms hitherto recorded as being native occur there. The finest specimens of *D. obovata* I have seen, however, came from Sligachan, Isle of Skye, collected in the summer of 1888 by the Revs. E. F. and W. R. Linton. Mr. C. Bailey possesses it from Thorne Moor, Yorkshire (J. Hardy, 1846); Boat of Garten, Easterness, July, 1887 (G. C. Druce); Crewe of Kintail, West Ross, y, 1881 (G. C. Druce); and European specimens from Lac de Lispach (Vosges), France: Billot Exsiccata No. 2,023, Wirtgen 172, Gérardmer, F. Schultz 435$\frac{b}{1}$; Bergzabern, Palatinate, F. Schultz 435; and Schwarzsee, Reichenbach 1078. I have it from the Lac de Lispach (*v. supra*) collected by Buchinger, *prope Salisburgiam* (Salzburg, 1835, C. B. Lehmann—these two from the Boswell (Syme) Herbarium of Europe and North temperate zone, purchased by me in 1889.

In conclusion, the following remarks about the general distribution of this interesting family (the *Droseraceæ*) may be interesting.

In addition to the three European species just alluded to, which get rarer or altogether absent in the Mediterranean region, while in Spain and Portugal the handsome and local *Drosophyllum Lusitanicum* alone is found, we find the genus unrepresented in N. Africa, south of the Sahara; only two or three species have as yet been detected in Tropical Africa; six, however, occur in the more southern

(Cape) regions of that continent, of which by far the most conspicuous is the beautiful *D. cistiflora* (Linn.). Only three species occur in India, one being very widely diffused; very few or none in Central Asia; China five, of which two occur in Japan. North America boasts of seven, as well as *Dionæa muscipula* (Ell.); Central and South America twelve or fourteen, of which *D. uniflora* (Willd.) is peculiar to Fuegia; New Zealand seven, four of which are also found in Australia. In this latter continent all the remaining species, some of them very handsome, are found, 48 in all, and very nearly all peculiar to this region. The two small genera, *Roridula* and *Byblis*, each containing two species, occur in the Cape district and Australia respectively.

I exhibit specimens of this genus from most of the regions above-named, which will give a very good idea of its salient points.

A new Symbolic Treatment of the Old Logic. By Joseph John Murphy. Communicated by the Rev. Robert Harley, M.A., F.R.S., Corresponding Member.

(Received January 14th, 1891.)

"All knowledge is relative:" that is to say, all knowledge is knowledge of relations; and every proposition is the assertion of a relation. The old logic is the theory of the formal properties of a particular set of relations, which have been variously defined as those of inclusion and exclusion—those of identity and difference—and those of coexistence and non-coexistence. All these are in effect the same—the three following propositions are evidently synonymous expressions, though expressed in three different ways:—

> The species Man is included in the class Rational.
> The species Man is indentical with part of the class Rational.
> The other attributes of Man coexist with the attribute Rationality.

In the present essay, the first of these three expressions of the relation is adopted. The relations treated of are defined to be those of total and partial inclusion and exclusion as between classes, and between groups of cases.

In logic, as in mathematics, literal symbols may be used both for the terms between which the relations subsist, and for the relations themselves. The former are called absolute, the latter relative terms. We cannot do without symbols for the former, if we are to use notation at all; but whether we use relative symbols will depend on our immediate

purpose in exposition. Every proposition and process known to the old logic may be shown with equal clearness without, or with, the use of symbols of relation, but not with equal neatness and conciseness.

The "logic of relatives" is not a distinct branch of the science, but only a distinct treatment of it. This is so at least within the limits of the old logic, though the higher branches of the science can scarcely be studied at all without using such symbols.

I use Roman letters for the absolute terms, and italics for the relative ones; and, following De Morgan, I use capitals for positive terms, and the corresponding small letters for the corresponding negatives. Thus if A, for instance, is taken to signify matter, a signifies whatever is immaterial.

Following Boole, I use 1 as the symbol for everything—not necessarily the entire universe, but the totality of things that form the subject of discourse; and 0 as the symbol for nothing, or that which has no existence, though it may be described, *e.g.*, a dragon or a centaur. Thus the equations

$$A = 1 \quad \text{and} \quad A = 0$$

signify respectively "A is coextensive with the universe," and "A does not exist." But if we use, as we may do, our absolute terms to signify not things but propositions, these equations will respectively assert "A is true" and "A is false."

As implied above, the copula = signifies indentity or constant coexistence. The copulas $<$ and $>$ signify inclusion within a class; thus, the inequation

$$A < B$$

states that A is included in B. But if, as before, we take A and B as the symbols not of things but of propositions, it states that the case of A being true is included in the case

of B being true; or, in simpler language, that if, or when, A is true, B is true also.*

Before going any further, we have to consider the question, which is important as one of procedure though it is not one of fact or law, whether we assert the existence of whatever we make the subject of a proposition. In common discourse we usually do so, unless we guard our meaning; but anything corresponding to parenthetical clauses for such a purpose would be unmanageable in logic; and the implication that existence is generally asserted of every term would lead to false results. The following instance, though not in this precise form, is mentioned in Mill's Logic:—"A dragon is a serpent; a dragon breathes flame: therefore some serpents breathe flame." This is in form exactly similar to the following, which is a valid syllogism according to the usual rules:—"Butterflies are insects; butterflies have wings: therefore some insects have wings."

Here are two syllogisms where the conclusion of one is true and that of the other false, for a reason which does not appear in the premises, viz.: that the subject of the premises is in the one case existent and in the other non-existent. The best way is to make no implication at all as to the existence of our subjects; and, in such propositions as the above, to substitute for the word "some," such an expression as "an undetermined quantity of," and, to represent it in notation by the algebraic expression $\frac{0}{0}$, which Boole sometimes uses in this sense. With this convention, the conclusion about the dragon is seen to be right, though without significance; a portion of the class serpents, *undetermined by the premises of the syllogism*, breathes flame; but in fact this portion is without extent, so that the proposition is neither true nor false. If the necessity for such a convention is

* This is the meaning constantly assigned to the symbols in MacColl's "Calculus of Equivalent Statements."

called a weakness in the system, it is a sufficient reply that logical science has never been expected to guarantee the *de facto* truth of premises; and it is equally unreasonable to ask it to guarantee the reality of terms.

When the absolute terms are taken to signify propositions, it would also be convenient to express "A is uncertain" by

$$A = \frac{0}{0}.$$

When we thus leave it undetermined whether any term, or name, represents an existing thing, it follows that the existence of its negative is left equally undetermined, and all our terms and their negatives are taken as equally real. As Jevons says, "Every term has its negative in thought." This conduces much to the symmetry of the system.

We have now to fix on our use of relative terms. I use E (the initial of *enclosure*) as the symbol of inclusion; so that the equation

$$A = EB \quad \text{or inversely} \quad B = E^{-1}A.$$

asserts that A is included in B, or is an enclosure of B; and B includes A, or is an includent of A. The symbol that I use for exclusion is N (the initial of *not*), so that the two equivalent equations

$$A = NB \quad \text{and} \quad B = NA$$

signify that nothing is both A and B. In this case I call A and B excludents of each other.

As with absolute terms, the corresponding small letter signifies the negative of the term. The negative of a relative term is called its contradictory. Thus the contradictories of

$$A = EB \text{ and } A = NB$$

are

$$A = \epsilon B \text{ and } A = nB,$$

signifying respectively "Some A is not B" and some "A is B."

These are respectively identical with the four relatives of the old logic, namely

Universal affirmative.	Universal negative.
Partial negative.	Partial affirmative.

which are, in the language and notation used here,

$\mathcal{E}$ Enclosure.	$\mathcal{N}$ Excludent.
ϵ Non-enclosure.	η Non-excludent or Participant.

These four relations between any two absolute terms A and B are set forth below in the old language and in the language used in this paper, with two corresponding notations, the one without, and the other with, relative terms :—

All A is B — $A < B$	No A is B; or — $A < b$
A is an enclosure of B. — $A = \mathcal{E}B$	Nothing is both A & B, A is an excludent of B — $A = \mathcal{N}B$
Some A is not B — $\overset{\circ}{-}A < b$	Some A is B; or — $\overset{\circ}{-}A < B$
A is a non-enclosure of B — $A = \epsilon B$	Some things are both A & B; A is a participant of B — $A = \eta B$

De Morgan has shown that the symmetry and completeness of the system demand the recognition of four other relations, contrapositive to these. The contrapositive of a relation is the relation that subsists between the negatives of its absolute terms; and the truth of the contrapositive necessarily follows from the truth of the proposition from which it is derived. I propose to indicate the contrapositive by the original relative term with V (the initial of *versed*) as an index.* Indicating the negatives of A and B by a and b

† De Morgan proposes this index, but as a mere synonym of the index – 1.

as already proposed, the contrapositives of the foregoing four propositions are as follows:—

All b is a; or all that is not B is not A $b<a$ a is an includent of b. $a=E^{\nu}b$	All that is not a is b; or Everything is either not A or not B $a<b$ a is an alternative of b, $a=N^{\nu}<b$
§ Some b is not a. $\overset{\circ}{\underset{\circ}{b}}<A.$ a is a non-includent of b. $a=\epsilon^{\nu}<b.$	Some things are neither a nor b $\overset{\circ}{\underset{\circ}{a}}<b$ a is a non-alternative of b. $a=\pi^{\nu}<b$

It follows from the nature of a relation, that if

$$A=EB, \quad \text{then inversely} \quad B=E^{-1}A,$$

that is to say, if A is an enclosure of B, B is an includent of A. But we have seen that if

$$A=EB, \quad \text{then} \quad a=E^{\nu}b,$$

that is to say, not-A is an includent of not-B; so that in this case the contrapositive relation is of the same form with the inverse relation. Symbolically,

$$E^{\nu}=E^{-1}.$$

This is true of the relation E (inclusion) and its derivatives by contradiction and contraposition; but it is not true of the relation N (exclusion), and its derivatives.

N and its derivatives are invertible. Symbolically,

$$N^{-1}=N.$$

E and its derivatives are not so. Those properties of the E

§ I have found it difficult to make this contraposition clear to myself without an example, and the following may be serviceable. Animals are either vertebrate or invertebrate, and animals, except those which have nothing analogous to blood, are either red-blooded or white-blooded. Some red-blooded animals are not vertebrate; and the contrapositive of this proposition is, that some invertebrate animals are not white-blooded.

group and of the N group, which are expressed by these two equations respectively, make it unnecessary to use the index -1 in the present system.

It is to be observed that the negative of a contrapositive is identical with the contrapositive of the negative.

Contraposition is an invertible operation. It is true of any relation R, that

$$(R^{\circ})^{\circ} = R.$$

The formal properties of any two propositions contrapositive to each other are the same, at least in all relations treated of in this paper.

We have now got eight relations, which are to be divided into two groups of four each in four different ways. I proceed to tabulate, thus arranged, in parallel columns, the propositions asserting these relations, in language and in my notation.

They are divided as opposites, into the E group and the N group. The relatives of the former group are uninvertible, those of the latter invertible.

All A is B A is enclosure of B $A = \mathcal{E}B$	Nothing is both A and B A and B are excludents $A = \mathcal{N}B$
Some A is not B A is non-enclosure of B $A = \epsilon B$	Some A is B A and B are participants $A = \eta B$
All not A is not B; whence All B is A A is includent of B. $A = \mathcal{E}^{\circ}B$	Everything is either A or B A and B are alternatives $A = \mathcal{N}^{\circ}B$
Some not A is B; whence Some B is not A A is non-includent of B $A = \epsilon^{\circ}B$	Some things are neither A nor B A and B are non-alternatives $A = \eta^{\circ}B$

The eight relations are also arranged as contrapositives to each other; these differ in *phase*:—

E Enclosure.	E^{v} Includent.
N Excludent.	N^{v} Alternative.
e Non-enclosure.	e^{v} Non-includent.
n Participant.	n^{v} Non-alternative.

They are also arranged as contradictories to each other:—these differ both in *quantity*, total or partial, and in *sign*, positive or negative. A proposition is positive, or affirmative, when its terms are of the same sign, and negative when they are of opposite signs. Thus the relation of alternative is a negative one, because its form is "not-A is B":—but that of non-alternative is positive, because its form is "some not-A is not-B." The relation which we call includent is, in the present system, doubly negative, and therefore positive, being here treated as the contrapositive of enclosure:—

$$A = E^{v}B$$

primarily means "All not-A is not-B." We also call syllogisms positive when the relations expressed in their premises are of the same sign;—negative, when they are of opposite signs. The conclusion of a positive syllogism is a positive proposition, and *vice versa*.

In the following, the positives are in the left column and the contradictory negatives at the right:—

E Enclosure.	e Non-enclosure.
E^{v} Includent.	e^{v} Non-includent.
n Participant.	N Excludent.
n^{v} Non-alternative	N^{v} Alternative.

They are also arranged with each partial opposite to its total.

E Enclosure (All A is B)	**u Participant** (Some A is B)
A Excludent (No A is B)	**o Non-enclosure** (Some A is not B)
E' Includent (All not-A is not-B)	**u' Non-alternative** (Some not-A is not-B)
N' Alternative (All not-B is A)	**o' Non-includent** (Some not-B is A)

There are some other relative terms which I shall have to use.

When 1 is used as a relative, it signifies identity :—the equation

$$A = 1B$$

asserts that A is one with B. The equation

$$A = (-1)B$$

asserts that B is defined as whatever is not A, so that (-1) has the meaning of *exclusive alternative*.

The use of 1 as a relative term makes it necessary to use U (the initial of *Universe*) in the sense that

$$A = UB, \quad \text{and conversely} \quad B = U^{-1}A$$

signify that A is co-extensive with the universe which contains B. And

$$A = OB, \quad \text{and conversely} \quad B = O^{-1}A$$

assert that A does not exist in the same universe with B.

Before we go on to the subject of syllogisms, we have to consider the combination into a resultant relation of two simultaneous relations between the same terms.

We have four total relative terms; and four objects admit of being combined into six pairs. The six pairs in this case, with the resultant relations into which they combine, are as follows :—they are stated both in language, and in "canonical equations" wherein the relations only are expressed.

All A is B $A = EB$	Nothing is both A and B, $A = NB$
All B is A $A = E^{\nu}B$	Everything is either A or B, $A = N^{\nu}B$
Therefore A and B are identical.	Therefore A and B are exclusive alternatives
$E \cdot E^{\nu} = 1$	$N \cdot N^{\nu} = (-1)$
All A is B $A = EB$	All B is A $A = E^{\nu}B$
No A is B $A = NB$	All not-B is A (or, everything is either B or A) $A = N^{\nu}B$
Therefore A does not exist.	Therefore everything is A.
$E \cdot N = 0.$	$E^{\nu} \cdot N^{\nu} = U$
All B is A $A = E^{\nu}B$	All A is B $A = EB$
No B is A $A = NB$	All not-A is B (or, Everything is either A or B) $A = N^{\nu}B$
Therefore B does not exist.	Therefore everything is B.
$E^{\nu} \cdot N = 0^{-1}.$	$E \cdot N^{\nu} = U^{-1}$

In the foregoing combinations, there is no middle term[1] and no elimination. A syllogism is defined as a combination of two propositions into one, with elimination of a middle term, and it may be treated as a multiplication of the two relations asserted by the two premises. Every two pairs of factors R and S admit of two multiplications

$$R \times S \text{ and } S \times R$$

and when R and S represent any two of the eight relations which we have considered, the two multiplications in no case give the same result. This however is not true of all logical relations:—*e.g.* let 1 mean the whole and $\frac{0}{0}$ a part, then

$$1 \times \frac{0}{0} = \frac{0}{0} \times 1$$

Before we consider syllogisms of the ordinary kind, let us consider a set of syllogisms whereof one premise asserts one of the eight relations expressed above, and the other asserts the relation of exclusive alternative, expressed by (-1). As the symbol of the combination of the two propositions into a syllogism, let us use the sign of multiplication $\times$. The forms of such syllogisms, in language and in notation, are the two following :—

All A is B ; or,	A is that which is not B ; or,
A is enclosure of B.	A and B are exclusive alternatives.
B is that which is not C ; or,	All B is C ; or,
B and C are exclusive alternatives,	B is enclosure of C.
Therefore no A is C ; or,	Therefore all that is not A is C ; or,
A and C are excludents.	A and C are alternatives.
$E \times (-1) = N.$	$(-1) \times E = N^{v}.$

In all such multiplications, or syllogisms, when the relative (-1) comes second it transforms the other relative into its opposite :—when it comes first, it transforms the other relative into the contrapositive of its opposite. The following is a tabular view of the sixteen possible syllogisms of this kind.

$E \times (-1) = N$	$(-1) \times E = N^{v}$
$E^{v} \times (-1) = N^{v}$	$(-1) \times E = N$
$N \times (-1) = E$	$(-1) \times N = E^{v}$
$N^{v} \times (-1) = E^{v}$	$(-1) \times N^{v} = E$
$e \times (-1) = n$	$(-1) \times e = n^{v}$
$e^{v} \times (-1) = n^{v}$	$(-1) \times e^{v} = n$
$n \times (-1) = e$	$(-1) \times n = e^{v}$
$n^{v} \times (-1) = e^{v}$	$(-1) \times n^{v} = e$

The relation expressed by (-1) is by definition negative. The equation $A = (-1)B$ is equivalent to $A = b$, and both mean that A is defined as all which is not B. It will be seen in the multiplication shown above, and it is invariably true in logic as in arithmetic, that the multiplication of

terms of like sign gives a positive product, and that of terms of unlike sign a negative one. Thus also

$$(-1)\times(-1)=1$$

We now come to syllogisms of the usual kind.

Following De Morgan, I write these with the "minor premise" (so called in the old logic) first. In any case this is an improvement, and the method of treating the syllogism as a multiplication makes it necessary.

We have seen that there are eight relations of total and partial inclusion and exclusion between any two absolute terms and their negatives, each of which may be asserted in a proposition; and as a syllogism consists of two propositions which constitute its premises, it is possible to state sixty-four forms of syllogism. Of these, however, only half are in the technical sense conclusive—that is to say, only half give results of similar form to any of the eight forms of premise. A syllogism with two partial premises is in no case conclusive. A syllogism with two total premises is always conclusive. A syllogism with one total and one partial premise is conclusive in half the number of cases.*

The following is a tabular view of the sixteen possible forms of proposition with two total premises, and the thirty-two forms with one total and one partial premise. The syllogisms are arranged in pairs:—those of the same pair are alike in all formal properties, and differ only in that their premises, and consequently their conclusions, are of opposite phases, being of mutually contrapositive forms.

Where the syllogism yields no conclusion, the right hand side of the equation is left vacant.

The relatives E and E^{v} alone are equal to their own second powers; this is the expression in the present system

* These thirty-two syllogisms are indentical with the thirty-two stated in De Morgan's "Syllabus of a proposed system of Logic," though both the notation and the arrangement are different.

of the canon of the "syllogism in Barbara," namely, that inclusion is a *transitive* relation :—if A is included in B, and B in C, then A is included in C, and conversely; so that the first two of the syllogisms are thus expressed in language :—

A is B : B is C : – therefore A is C.

A contains B : B contains C : – therefore A contains C.

The syllogisms of the first column have two total premises; those of the second column are derived from the first by substituting a partial for a total in the second premise, and those of the third column by the same substitution in the first premise; with the result, that where the conclusion of the first column is total, there is no conclusion in the second, and in the third the conclusion is the partial of that in the first; when the conclusion in the first column is partial, there is the same conclusion in the second column, and none in the third. The rationale of this will be best seen by taking as typical cases, and expressing in words, the syllogisms of the first and fourth lines of the tabular statement.

In line 1, column 1, the middle term is related *oppositely* to the extreme terms. B *includes* A, and *is included in* C. The conclusion is total :—A is C. In the second column of the same line, the premises are altered by substituting the partial for the total in the *second* premise, so that the syllogism becomes "B includes A, and (only) some B is included in C." This yields no conclusion. In the third column, the partial is substituted for the total in the *first* premise, so that the syllogism becomes "Some A is B, and B is C." This yields the conclusion "Some A is C," which is the partial of the first conclusion.

In line 4, column 1, the middle term is related *similarly* to the extreme terms. "Not-B is included in A, and not-B is included in C; consequently, some things are both B and C." (This, of course, implies our postulate

that every term has its negative). In the second column, the partial is substituted for the total in the *second* premise, and the premises become "All not-B is A;—Some not-B is C":—with the same conclusion as before, that "some things are both A and C." In the third column, the partial is substituted for the total in the *first* premise, and the syllogism becomes "Some B is not A:—all not B is C;" which premises yield no conclusion. Every syllogism in the following statement may be reduced to one of these six typical forms.

Same sign—same phase.

$E \times E = E$	$E \times n =$	$n \times E = n$
$E^{\nu} \times E^{\nu} = E^{\nu}$	$E^{\nu} \times n^{\nu} =$	$n^{\nu} \times E^{\nu} = n^{\nu}$
$N \times N = n^{\nu}$	$N \times e = n^{\nu}$	$e \times N =$
$N^{\nu} \times N^{\nu} = n$	$N^{\nu} \times e^{\nu} = n$	$e^{\nu} \times N^{\nu} =$

Same sign—opposite phases.

$E \times E^{\nu} = n^{\nu}$	$E \times n^{\nu} = n^{\nu}$	$n \times E^{\nu} =$
$E^{\nu} \times E = n$	$E^{\nu} \times n = n$	$n^{\nu} \times E =$
$N \times N^{\nu} = E$	$N \times e^{\nu} =$	$e \times N^{\nu} = n$
$N^{\nu} \times N = E^{\nu}$	$N^{\nu} \times e =$	$e^{\nu} \times N = n^{\nu}$

Opposite signs—same phase.

$E \times N = N$	$E \times e =$	$n \times N = e$
$E^{\nu} \times N^{\nu} = N^{\nu}$	$E^{\nu} \times e^{\nu} =$	$n^{\nu} \times N^{\nu} = e^{\nu}$
$N \times E = e^{\nu}$	$N \times n = e^{\nu}$	$e \times E =$
$N^{\nu} \times E^{\nu} = e$	$N^{\nu} \times n^{\nu} = e$	$e^{\nu} \times E^{\nu} =$

Opposite signs—opposite phases.

$E \times N^{\nu} = e^{\nu}$	$E \times e^{\nu} = e^{\nu}$	$n \times N^{\nu} =$
$E^{\nu} \times N = e$	$E^{\nu} \times e = e$	$n^{\nu} \times N =$
$N \times E^{\nu} = N$	$N \times n^{\nu} =$	$e + E^{\nu} = e$
$N^{\nu} \times E = N^{\nu}$	$N^{\nu} \times n =$	$e^{\nu} \times E = e^{\nu}$

The following are the same syllogisms, expressed in the terminology used in this paper:—

Enclosure of enclosure is enclosure.		Participant of enclosure is participant.
Includent of includent is includent.		Non-alternative of includent is non-alternative.
Excludent of excludent is non-alternative.	Excludent of non-enclosure is non-alternative.	
Alternative of alternative is participant.	Alternative of non-includent is participant.	
Enclosure of includent is non-alternative.	Enclosure of non-alternative is non-alternative.	
Includent of enclosure is participant.	Includent of participant is participant.	
Excludent of alternative is enclosure.		Non-enclosure of alternative is participant.
Alternative of excludent is includent.		Non-includent of excludent is non-alternative.
Enclosure of excludent is excludent.		Participant of excludent is non-enclosure.
Includent of alternative is alternative.		Non-alternative of alternative is non-includent.
Excludent of enclosure is non-includent.	Excludent of participant is non-includent.	
Alternative of includent is non-enclosure.	Alternative of non-alternative is non-enclosure.	
Enclosure of alternative is non-includent.	Enclosure of non-includent is non-includent.	
Includent of excludent is non-enclosure.	Includent of non-enclosure is non-enclosure.	
Excludent of includent is excludent.		Non-enclosure of includent is non-enclosure.
Alternative of enclosure is alternative.		Non-includent of enclosure is non-includent.

[*Physical and Mathematical Section.*]

January 14th, 1891.

JAMES BOTTOMLEY, B.A., D.Sc., F.C.S., President of the Section, in the Chair.

Mr. THOMSON showed some experiments with respect to surface tension, and drew special attention to the following:—(*a*) In which a bubble was attached to an aluminium wire ring by a thread so as to float in the air as a captive balloon. (*b*) In which *three* bubbles were blown on the top of one attached to a wire ring; on the surfaces of the four coming together very definite outlines showed themselves, *e.g.*, three planes where the three bubbles rested on the fourth, and three planes where the three bubbles came together. (*c*) In which, with two bubbles of unequal size, the size of one gradually, by blowing into it, approximated to that of the other, the junction of the two bubbles becoming a flat surface or film.

On the Source of some remarkable Boulders in the Isle of Man. By Percy F. Kendall, F.G.S. Communicated by Thomas Kay.

(*Received March 26th, 1891.*)

The determination of the source whence the erratic blocks of any given area have been derived has always appeared to me to be the first, and at all times the most important, part of the work of a student of Glacial Geology. In comparison with it such details as the character, and, especially, the colour of the deposits, must be assigned an altogether subordinate importance. The erratics of Lancashire and Cheshire have long been well-known, so far as regards their general grouping; and the labours of such investigators as Mr. DeRance, Mr. Mackintosh, and Mr. Mellard Reade, have made geologists familiar with the fact that, in the area in question, the far-travelled erratics, with some half-dozen of individual exceptions, are traceable to a source within the area draining into the Northern and North-eastern portion of the Irish Sea. The exceptions to this rule are, certain Ophicalcites which have been met with on the Ship Canal near Barton, and two specimens of a coarse Ophitic Dolerite—one found near Congleton, and recorded by Messrs. Coutts-Antrobus and Hatch,* and the other found by myself on the Ship Canal, at Bob's Bridge, near Moore. The flints, which are to be found in almost every section in the Lancashire lowlands, are—so far as I can ascertain—invariably beach- or river-worn pebbles, and, therefore, not of any value as indications of the direction of transport.

* Brit. Assoc. Report, 1890.

In the Isle of Man many of the rocks which occur in the Lancashire Glacial deposits are to be found, though in widely different proportions; thus, the Eskdale Granite, which is so common on the mainland, is very rare in the Island, or possibly absent, and the same is the case with the other Lake District rocks, but their place is taken by Granites, Quartz-porphyries, and other igneous rocks, which are clearly traceable to the great intrusive masses of Galloway. Intermingled with these, to me, familiar rocks are many which were entirely strange, and most prominent amongst them a fine-grained granitic rock, which contained patches of a blue mineral, presenting cleavages, which suggested to me that it might be Riebeckite, the rare blue variety of Hornblende. As this mineral was known in the British Isles only as a constituent of a rock at Mynydd Mawr, in Carnarvonshire, I submitted a specimen to Mr. Alfred Harker, of Cambridge, who has described the Welsh rock, but he did not consider that the Manx boulders could have been derived from the Mynydd Mawr mass, as its structure and appearance were different.

In view of this opinion, I allowed the question to remain undecided, until a new stimulus was given to my curiosity by the discovery of a pebble of the same rock on Moel Tryfan, Carnarvonshire, a hill about 2 miles distant from Mynydd Mawr. From the occurrence of the rock in great abundance in the Isle of Man, I was convinced that it could not be of Welsh origin, and its absence from Lancashire rendered it very improbable that it could be a Galloway rock.

I therefore sent a specimen to Professor Cole, of Dublin, who confirmed my determination of the Riebeckite, but could not recognise any similarity to any Irish rock. He considered the rock of such interest as to be worthy of description, and accordingly prepared some notes upon it to be presented to the Mineralogical Society at their

January (1891) meeting. Meantime, I sent another specimen to Mr. J. G. Goodchild, of Edinburgh, and received from his colleague, Mr. A. Macconochie, a letter in which he expressed the opinion that the boulder resembled a rock found in Ailsa Craig, an opinion with which Mr. B. N. Peach concurred.

By a singular coincidence, Mr. J. J. H. Teall, of H.M. Geological Survey, described the Ailsa Craig rock at the same meeting as that at which Professor Cole's note was read. Mr. Teall points out four several particulars in which my rock resembles that of Ailsa Craig, and differs from the Mynydd Mawr examples.

In view of the concensus of opinion in favour of the identification of the rock with the Scottish granite and against its allocation to North Wales, I cannot resist the conclusion that boulders from Ailsa Craig were actually carried to the Isle of Man and North Wales during the Glacial Epoch. This is the first example of the occurrence of rocks from the Clyde Basin as erratics in the basin of the Irish Sea.

The discovery throws a remarkable light upon the speculations of those able investigators, Mr. John Horne and Professor James Geikie.

Mr. J. Horne long ago* showed that the Isle of Man had been glaciated by a great sheet of ice coming down from the mountains of Galloway, and aided by contingents from the Lake District and Ireland. He pointed out that a deep submarine rock-channel existed round the N.E. coast of Ireland, from Rathlin Island down to about the latitude of Dublin, and he suggested that this might be a "deflection basin" cut out by ice which came down the Firth of Clyde, was cleft by the Antrim coast line, and flowed, one element westward into the Atlantic, and the other southward, through the North Channel into the Irish Sea.

* *Trans. Geol. Soc. Edin.* Vol. iii., part 3.

Professor James Geikie* developed this idea, and showed that the striæ upon glaciated surfaces in Ayrshire, and down to the Mull of Galloway, showed a deflection coastwise, as they were traced down from the hills, and that they furnished clear proof of the flow of ice from the Firth of Clyde into the Irish Sea.

This evidence was perfect so far as such evidence could be, but there has been lacking the testimony of boulders, which I now supply. It must be distinctly understood that I do not express any opinion whatever. on the vexed question of the origin of lake-basins, but merely point out the corroboration of Mr. Horne and Professor Geikie's opinion that ice came from the Clyde into the Irish Sea.

There is a further point to which I would allude, viz :— the altitudes attained by these boulders. In the Isle of Man, foreign boulders are traceable only to a very moderate height, and the highest point to which I have traced the Ailsa Craig rock is at the dam of the Ramsey Waterworks, in Ballure Glen. The altitude reached on Moel Tryfan is about 1,350 feet, whereas the total height of Ailsa Craig is only 1,097 feet, so that, assuming that the Riebeckite rock attains to the actual summit, it must have undergone an uplift of 250 feet in its transit to Moel Tryfan.

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* *Great Ice Age* (2nd ed.) p. 294.

[*Microscopical and Natural History Section.*]

Ordinary Meeting, February 16th, 1891.

ALEX. HODGKINSON, M.B., B.Sc., President of the Section, in the Chair.

Mr. P. CAMERON exhibited a number of galls, and gall-making insects.

The PRESIDENT and Mr. R. E. CUNLIFFE exhibited volcanic dust, from Krakatoa and New Zealand.

Ordinary Meeting, February 24th, 1891.

JAMES BOTTOMLEY, B.A., D.Sc., F.C.S., Vice-President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Mr. FRANCIS JONES, F.R.S.Ed., F.C.S., and Mr. SAMUEL OKELL, F.R.A.S., were appointed auditors of the Society's accounts for the current year.

Professor OSBORNE REYNOLDS gave an account of a phenomenon observed in the engineering laboratory of the Owens College in connection with the dense fog which had prevailed during the day. Some new belting had been kept running from eleven to three o'clock at the rate of about 40 to 50 miles per hour. The belting was new and bright when started, but on being stopped was found to be quite black, being loaded with dirt collected during its rapid passage through the foggy air. It was much the dirtiest thing in the laboratory. Professor REYNOLDS pointed out the analogy to the dirtiness of an express train, the phenomenon in both cases being due to the fact that a rapidly moving body comes in contact with a greater quantity of air in a given time than a stationary body, and therefore picks up a greater quantity of atmospheric pollution.

Professor REYNOLDS also exhibited two harmonic analysers affording a means of ascertaining the periods of free vibration of structures, or members of structures, and communicated the substance of a paper on the subject.

Mr. FARADAY read the first portion of a paper entitled, "Thoughts on Credit Money, and on the function of the Precious Metals as Distributors of Wealth."

On Two Harmonic Analyzers. By Osborne Reynolds, LL.D., F.R.S., M.Inst.C.E., Professor of Engineering, the Owens College.

(*Received April 2nd, 1891.*)

The object of these instruments is to afford a ready means of ascertaining the *periods* of *free vibration* of structures or members of structures. If any portion of a material structure (*i.e.*, an elastic structure) is disturbed from its normal position of equilibrium and suddenly released, the structure is thrown into a complex state of vibration, which gradually subsides. While the vibration lasts each point in the structure goes through movements which may be very complex, but which are, nevertheless, compounded of simple periodic or harmonic movements, each simple movement taking place in a definite direction as well as having a definite period.

The art of measuring and recording the complex movements at a point of the earth during an earthquake has long been a study, and the seismometer of Professor Ewing has been applied to record the movements of points of various structures when subjected to disturbances. The principle of these seismometers consists in attaching a weight to the point of the structure to be examined, by attachments of such slight elasticity, that the disturbances communicated to the weight are insensibly small, and the weight remains sensibly steady amid the surrounding vibrations, and forms a steady observatory from which the vibrations may be measured. This measurement is effected by causing pencils vibrating with the structure to describe lines on cards attached to the steady weight, or *vice versa*, the cards being fixed, or

having a time movement. In this way the complex motions of the points are beautifully recorded, as in Prof. Ewing's experiments on the Tay Bridge, and Prof. J. Milne's numerous experiments in railway carriages, &c.

Such curves represent the complex movements of the point of the structure examined; and any analysis of the motion into its simple periodic components remains to be accomplished by mathematical reduction—or by such instrumental synthesis as that which may be effected in Sir William Thomson's "Harmonic Analyzer."

The Harmonic Analyzers about to be described differ essentially from the seismometer in that they do not measure or record the actual motions of the structure, while they single out and exaggerate any component periodic motion according to its *period* and direction, which are defined in the instruments. The principle of these Harmonic Analyzers is that of the accumulation of motion which takes place when a weight is subject to a periodic disturbance which coincides in period and direction with that of free vibration of which the weight is susceptible.

If a small weight w be elastically attached to a much heavier weight so that it requires a definite force (Ef) to disturb the weight (w) through a distance l, the large weight remaining at rest; then, if released after any disturbance, the small weight w will vibrate in the direction of disturbance, and with a constant period

$$\left(2\pi\sqrt{\frac{w}{gE}} \text{ in seconds}\right)$$

i.e. in the period of free vibration of the small weight.

If the small weight be at rest and the large weight be subject to a periodic disturbance having a period $\left(\frac{1}{n}\right)$; then, if this period is larger than the period of free vibration of the small weight, *i.e.*, if

$$\frac{1}{n} \text{ is smaller than } 2\pi\sqrt{\frac{w}{ge}}$$

the small weight will follow essentially the movements of the larger weight as if rigidly attached, while if the period of motion of the larger weight is smaller than that of the period of free vibration of the small weight, the small weight will remain virtually at rest. But when the period of motion of the large weight coincides with the period of free vibration of the small weight, the small weight will take and accumulate the disturbance, oscillating with increasing amplitude until it reaches such an extent that the energy dissipated is equal to that received from the disturbance. If the elasticity of the connections be fairly perfect, the amplitude of the small weight will be very considerable, although the disturbing motion is otherwise insensible.

If the small weight (w) has only one degree of freedom, *i.e.*, if the elasticity of the connections is not equal in all directions, there will be three axes of elasticity, and if the elasticities along two of these directions are much greater than the third this is the direction of freedom; then, when the period of free vibration along the third axis, *i.e.*, in the direction of freedom, coincides with the period of disturbance, the small weight will only take up the disturbance when this has a component in the direction of freedom; that is, if the direction of the disturbance is at right angles to the direction of freedom, there will be no vibration. So that in this way the direction of the disturbance may be ascertained, or *vice versa*.

Similar results follow if, instead of the disturbance coming through the elastic supports, the body be subject to a synchronous periodic force. If the period of the force were not synchronous with any of the three periods of free vibration corresponding respectively to the three axes of elasticity, the resulting vibration would, as before, merely correspond with the time effect of the force, but on coincidences with any one of these, unless the direction of

the disturbance were at right angles to that of the axis of elasticity, the body would accumulate the disturbance.

It thus appears that, if a structure is in a state of vibration, the periods of free vibration and their directions may be ascertained by an Harmonic Analyzer consisting of a small weight with elastic attachments, so adjustable that the period of free vibration of the weight can be varied to any required extent, and the direction of such free vibration turned through all requisite angles.

This may be accomplished in many ways. That which I have so far adopted with satisfactory success has been very simple.

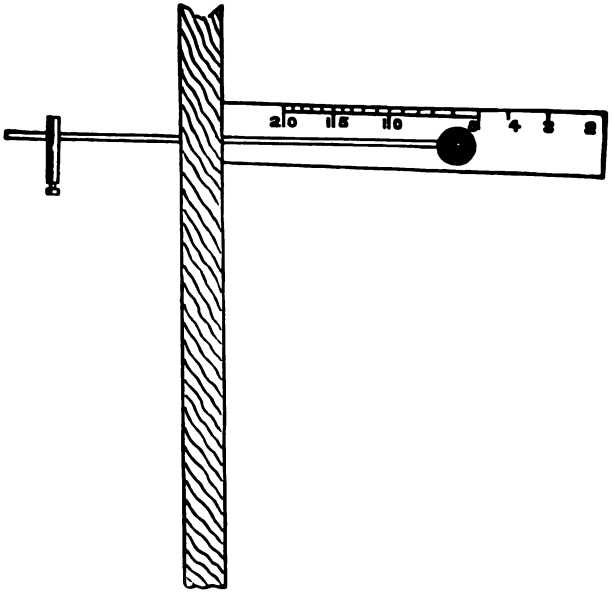

Fig. 1.

It consists, as shown in Fig 1, essentially of a base formed of a bar of hard wood, one-and-a-half inches square, and

two feet long, a cross notch being cut in one end to enable this end to be held against any point of the structure with less chance of slipping. About four inches from the notched end, right across the axis of this bar, is a hole, in which is fitted, with moderate tightness, a piece of straight steel wire, one-eighth of an inch in diameter, and 18 inches long. On one end of the wire is a ball of lead, about 2 oz., through the centre of which is a small hole at right angles to the wire, in which is fixed a small graphite pencil. On the other end of the wire is a carrier, to afford handhold for the purpose of adjusting the wire in the hole.

When the carrier is pushed right up to the wood, the ball, if disturbed, will vibrate in any direction perpendicular to the wire so as to make about 200 oscillations a minute, which is slower than any period it is required to measure. As the carrier is pulled back, and the wire between the base and the ball shortened, the rate of vibration increases, until, when the wire is only 1½ inches long, the ball, when disturbed, gives out an audible note of about 2,000 vibrations a minute.

The instrument is used by holding in one hand the longer end of the wood and pressing the notched end hard against the point of the structure of which the motion is to be analyzed, the carrier having previously been pushed up to the wood, then, with the free hand, the carrier is pulled steadily back, the ball being carefully watched. As by the shortening of the wire between the base and the ball the free period of vibration of the ball is diminished, and comes near to any period amongst the vibrations in the structure, the ball is seen to take up the vibration in beats with intervals of rest; and a very little more careful adjustment is sufficient to bring the period into coincidence, when the ball continues vibrating with the structure, having the appearance in Fig. 2.

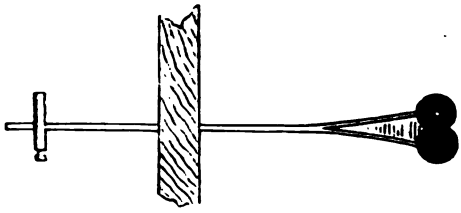

Fig. 2.

The period of the Analyzer having been thus adjusted to that of one of the periods of free vibration of the structure, the period is ascertained either by adjusting the Analyzer so that the pencil in the ball may oscillate in contact with the paper on a chronograph, or by measuring the distance of the ball from the wood on a scale, previously adjusted by aid of the chronograph to give the number of vibrations per minute.

Extreme accuracy of determining the periods has not so far been an important consideration. The readings on the chronograph were only taken to about 10%. But that the Analyzer is susceptible of much greater accuracy is shown by the fact that several different adjustments to the same period in the structure brought the wire into exactly the same position.

Its power of analyzing complex vibrations is so far unqualified. It was invented for the purpose of determining the period of a particular vibration—in a very stiff iron structure subject to the periodic disturbance of the belts from two engines running at high speed, and the centrifugal action of such want of balance as there might be in heavy pulleys, three feet in diameter, and running at 500 revolutions per minute. The vibration was very slight—nothing more than a slight tremor could be felt with the hand. The periodic disturbances were about 500 per minute, and these came out clearly, but small, in the Analyzer when adjusted to these periods—but the periods of free vibration of one of the members, 720 per minute, caused an amplitude of

half an inch in the ball, and that of another, 1.270, was easily identified.

The instrument already described can clearly only be used on a structure while it is so disturbed as to set its members vibrating. Such disturbances can generally be set up by a shock of some sort, but when it is necessary to cause artificial disturbance, it is better to adopt a periodic disturbance of such varying period as will come gradually into coincidence with the periods of free vibration, bringing these vibrations out separately, when they will be readily identified with the Analyzer, if not otherwise perceptible.

For this purpose, in 1887, I adopted the following method:—A small cast-iron pulley, 6 inches in diameter, very much out of balance, was mounted on a small frame that could be clipped on to any part of the structure, and a cord passed over this pulley on to a larger wheel, which was turned by hand. In this way the unbalanced wheel was driven at a gradually increasing rate until steady vibrations in the structure were observed, then these coincided with the period of the unbalanced wheel, and this was ascertained to be about 1,200 by counting the revolutions of this hand-wheel. At this speed the disturbing force resulting from the unbalanced weight, 2 lbs. on a radius of 2 inches, would be 40 lbs. The structure thus under examination was an iron standard, very stiff. A theodolite was adjusted, with the cross curves on a mark on the top of the standard, which, when the period of the small unbalanced wheel coincided with that of free vibration, was seen to move as much as one-twentieth of an inch. Chains were then attached to the top of the standard, and by means of blocks, a horizontal force of a ton was thrown on to the top of the standard, when it did not yield more than two-hundredths of an inch. So that the deviation caused by the periodic force of 40 lbs., in such coincidence with the period of free vibration as could be attained with the hand-wheel, was three times as great as that which resulted from a direct statical force of one ton.

Ordinary Meeting, March 10th, 1891.

EDWARD SCHUNCK, Ph.D., F.R.S., F.C.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Mr. WILLIAM BROCKBANK, F.L.S., F.G.S., read the first portion of a paper on "The Occurrence of *Spirorbis* limestone in the West Cumberland Coal-field, near Whitehaven."

Mr. PERCY F. KENDALL, F.G.S., remarked on the peculiar character of the grit from the boring, which, he said, seemed to indicate that the rock had been at some time exposed; he also considered that the volcanic ash fragments furnished no evidence of contemporary volcanic action, and preferred to regard them as carried pebbles, as are the felspar and quartz. Mr. C. E. DE RANCE, F.G.S., considered that Mr. BROCKBANK'S discovery was one of great importance, and noticed that it corroborated to a large extent the opinion long ago held by Professor HARKNESS of the geology of the Whitehaven district.

The Rev. T. P. KIRKMAN, M.A., F.R.S., communicated a paper on "Functions from Groups."

Mr. FARADAY read the concluding portion of a paper entitled "Thoughts on Credit Money, and on the function of the Precious Metals as Distributors of Wealth," of which the first portion was read at the previous meeting. In the discussion which ensued, Mr. ROBERT BARCLAY observed that the philosophic study of money had been strangely neglected by writers on economics, and that much good would be done if scientific men would apply their methods to it. The amount of metallic

money in relation to credit money is almost insignificant, yet it is all important. He was much struck with the author's definition of credit as "the monetisation of commodities." It was undoubtedly correct. The leaders of economic thought, whose writings are still authoritative in England, say the school of John Stuart Mill, never gave the subject of money full consideration. They never asked the question, how it was that silver money and gold money, in their days, maintained such a steady relation to each other, but seem to have rested in the belief that supply and demand accounted for it, overlooking the fact that the supply of the two metals had varied very greatly, and being unconscious of the enormous influence of specific national laws then in operation. This only became apparent from the effects of the closing of the French mint to the free coinage of silver. In his chapters on international trade, John Stuart Mill always speaks of "the precious metals" as the basis for adjustment, and repeatedly reminds his readers that by "the precious metals" he means silver and gold. In his days silver and gold were one thing, unitedly they formed, to apply Mr. Faraday's term, for all the world true monetary "ions."

Thoughts on Credit Money, and on the Function of the Precious Metals as Distributors of Wealth. By F. J. Faraday, F.L.S., F.S.S.

(Received April 7th, 1891.)

Toutes les théories sociales peuvent et doivent s'inspirer de trois idées: l'idée de justice, l'idée d'utilité, et l'idée de liberté individuelle.—PAUL LEROY-BEAULIEU.

I.

The inequality in the distribution of wealth has become the peculiar economic problem of the age. It is not denied that the position of the working-classes has improved with the progress of science and its application to industrial production; and no scientific mind dreams of the possibility of an absolutely equal distribution of wealth. The natural inequalities of mankind will continue to exist; a complete levelling would be in the economic world what the dissipation of energy would be in the physical universe. In a former paper, read before the Society (*Proceedings*, Vol. XXVI., 1887), I remarked that different qualities of labour might be regarded as different quantities of labour; and, adopting the idea of a unit of labour, which seems to underlie the teachings of Rodbertus and Karl Marx, as the measure of payment, the skilled labourer would still, necessarily, receive a greater reward than the unskilled in proportion to the greater quantity, or number of units, of his labour, and would, therefore, be a relatively wealthier man.

But, while rejecting the illusions of the collectivists, and admitting that the position of the working-classes has improved, all thoughtful men are disposed to ask the

question whether there is not a greater tendency to the congestion of wealth in the hands of a section of the community than can be regarded as a necessary consequence of the varying qualities of mankind, or of that hereditary transmission of wealth, which is one of the conditions of the accumulation which makes possible the general advancement of the community? In other words, bearing in mind the vast increase in productive power due to the advancement and application of science, has the position of the labourer improved in a reasonably proportionate ratio? The conviction that it has not done so, and the desire to remedy the anomaly, are at the base, not merely of the various present-day State-help movements, but of trades unionism, and especially of what is known as the new trades unionism, co-operation, profit-sharing, and other economic experiments; and it really inspires the further studies of economists and all would-be social reformers.

The problem, as it presents itself to sober minds, may be stated as follows: Is it possible, without undue interference with individualism, to diminish the inequalities in the distribution of wealth? Is a distribution approximately proportionate to the quantitative (or qualitative) relations of the services rendered—the value of such services being still estimated strictly according to what they can freely command in exchange in the market—consistent with the free play of natural economic laws, including the law of supply and demand? If so, then what are the conditions which check such distribution?

In the consideration of these questions, we may leave out the doctrine of Malthus. Up to the present the means of subsistence have increased in a far greater ratio than population. Moreover, the problem immediately in hand is not, as I view it, concerned with the consequences of mere individual imprudence, recklessness, or vice. These are

questions which, though they have a bearing on the general question of the distribution of wealth, are not involved in the particular case of the distribution of the wealth produced between those having some direct proprietary right to a share of the product, whether for services effectively rendered or as the lenders of the materials and the implements or agents of production, including land. An increase of capital in a greater ratio than population implies an increased competition for labour and a consequently higher proportionate reward for labour, other things remaining equal. This is involved in John Stuart Mill's theorem that "increase of capital gives increased employment to labour without assignable limit"; and also in Adam Smith's teaching that increase of capital tends to lower the profits of the capitalist.

Assuming, then, the fundamental "rights" of labour; defining labour as the exercise of personal qualities, whether of mind or body, resulting in production or services to the community; admitting the qualitative differences of services (as for instance between those of the capitalist employer, the opera-singer, the painter, the speculator, or the man who follows the plough) as quantitative differences determined by their respective values in exchange; and even putting the service of the lender of the agents or implements of production (the landowner or the lender of capital who receives a fixed interest and takes no risk) in the same category; and granting that free competition, and the unrestricted play of the law of supply and demand tend to an equitable proportionate distribution of wealth in accordance with the best interests of each member of the community and of the community as a whole—then it is clear that any excessive congestion of wealth must be due to some conditions which result in what has been described as "an unearned increment."

I do not think that, after due consideration of the

admissions in the last paragraph, anybody will take exception to my employment of the term "unearned increment." Those admissions concede the rights of inheritance, the right of each member of the community to obtain the largest reward he can for the judicious employment of his capital or of the faculties, knowledge, or skill which he possesses. They imply the free play of individualism, recognition of the full rights of property, and they characterise all personal action, even that of the mere lender or investor, as labour or service of a certain quality, the quantitative value of which depends on the quantity of the labour, or the products of labour, which it can secure in exchange under the unrestricted operation of the law of competition.*

How, then, can an "unearned increment" arise? Hitherto it has been regarded as arising most conspicuously from what John Stuart Mill has described as the "natural monopoly" of land; and its remedy in this case is the object of the proposals of Mill and Mr. Henry George for the taxation or nationalisation of land. I do not propose to discuss the land question; but, in passing, it is necessary to make one or two remarks as part of the line of thought which I am following. The monoply of land by the State would not necessarily be a violation of what we understand by natural economic laws; it would be merely an extended application of the joint-

* I willingly admit that the term "unearned increment" is objectionable; it is not sufficiently neutral as an economic expression, for it seems to imply a conclusion which may be a matter of argument. I have adopted it, however, because it is more generally understood than the terms "plus valeur," "plus value," or "surplus value." Moreover I do not think that Sir Louis Mallet, who has so vigorously denounced Mill's employment of it, would have objected to its application in the particular case which I am about to consider, that of a "surplus value" arising, not from a natural, but from an artificial monopoly. His enthusiasm for the principles of "free exchange" made Sir Louis Mallet, the disciple, friend, and successor of Cobden, an opponent of gold-monometallism and an advocate of the joint standard of gold and silver.

stock principle. The real question, then, in regard to land is whether (omitting from the consideration all idea of confiscation) nationalisation would be more economical than private ownership; that is, whether it would pay the shareholders. The difference between a huge corporation like the Great Western Railway Company, owning about 2,500 miles of railway, and the Indian Government, owning about 12,000 miles, is merely one of degree; and the desirableness of one or the other proprietorship obviously depends on local circumstances. There can be no cast-iron rule; that which might be truly economical in India would not necessarily be so in this country. It is too often overlooked that the proverb "circumstances alter cases," has a very serious application in economics. In his book "Le Collectivisme," M. Paul Leroy-Beaulieu has advanced very cogent arguments tending to show that the cessation of private ownership in land would not be economical; in short, that it would tend to diminish the general wealth of the community. Though benevolently disposed towards some of the ideas of the collectivists, M. Emile de Laveleye has given, in his various writings on Continental agriculture, very forcible illustrations of the economic advantages of peasant proprietorship, which is, after all, an extreme form of private ownership. In his posthumous essay on "The Law of Value and the Theory of the Unearned Increment," Sir Louis Mallet has also vindicated the economic theory of property in land. (*Free Exchange.* By the Right Honourable Sir Louis Mallet, C.B. Edited by Bernard Mallet.) If State ownership resulted in a decline of economic efficiency—that is, if the land became less productive, the lower classes might be poorer than at present, even though the aggregate wealth were more equally distributed. Now, it would surely be no satisfaction to the working-man to know that his share of the production bore a greater ratio to the share of the capitalist than

before, if the absolute quantity received by him were less than before.

A close study of what are known as the natural laws of economics—such as that of supply and demand—reveals the fact that their saving, and, indeed, essential principle is that of an automatic compensatory action. An extreme tendency in any direction calls into operation a checking or balancing movement. Thus, an increased demand for any article, by raising its price and increasing the profits of the capitalist engaged in its production, stimulates an increased supply of that article by attracting capital to the industry; this movement tends to make good the relative deficiency, and thus to check the advance of prices. Again, the increasing employment of capital in a highly profitable industry increases the demand for labour in that industry, and, therefore, tends to raise wages; hence, the appearance of a higher profit for the capitalist, analogous to the "unearned increment" of the landowner, calls into play conditions which promote its distribution. It may be said that the true test of the soundness, or naturalness, of any economic arrangement is its subservience to such compensatory action in accordance with a ruling principle of nature. Now there is grave reason to doubt whether the State monopoly of land, any more than any other monopoly, would be consistent with the possibility of such action and reaction. On the other hand, it is quite clear that the "unearned increment" arising from the private ownership of land is to some extent under the law of compensatory action which tends to promote distribution. A rise of rents in this country induces, for instance, the cultivation of the cheaper lands of the colonies, the United States, and other regions of the globe; and the competition of the grain and other agricultural produce received thence has tended to reduce rents again by lowering the profits of farming and diminishing the competition for farms. The demand for

manufactured products in exchange for the produce imported has tended to draw labour from the rural estates to the manufacturing districts, and it would appear that the natural consequence would, in the end, be higher agricultural wages; the payment of such wages should imply more efficient labour, and, consequently, increased production from the land. This has avowedly been the result in the north of England, where agricultural wages are higher than they are in the east and south, and farming is, nevertheless, more profitable. Such a process, though it may be slow, clearly tends to promote the distribution of wealth.

It is, probably, in consequence of the attention given to Mill's "natural monopoly" of land and to Anderson and Ricardo's theory of rent, before the development of railways, steam navigation, and ocean telegraphy had, by practically annihilating distance, brought new factors into play, that the influence of monetary law on the distribution of wealth has been so generally overlooked. I have been led to inquire into this influence. We have seen that such undue congestion of wealth as that under consideration arises, according to collectivist theories on the subject, from the development of an unearned increment from capital or land; that is, an increase of value due to circumstances or conditions which the recipient has had no part in bringing about, or, in other words, an income which is not in any sense the payment of additional services rendered. With such services I would include the service of the speculator, who stores the surplus abundance of to-day to provide for the deficiency of to-morrow. Such increment is, of course, based on an increase in the exchangeable, or loanable, value of the thing possessed, caused by arbitrary influences of a temporary or permanent character. Thus, meteorological conditions, in bringing about a failure of growing crops in the United States and India, may greatly enhance the exchangeable

value of grain produced in England. Such arbitrary influences on the value of commodities have the most permanent effect on articles not producible at will, because such commodities are sheltered from the law of automatic compensation, according to which a rise in value stimulates supply sooner or later.* Land is not producible at will; but the opening up of previously uncultivated areas of the surface of the globe operates within certain limits in the same way as an increase in the supply of commodities producible at will, by checking the advance of rents. In gold, however, we have a commodity not producible at will, or, in only a very restricted sense of the word, the present exchangeable value of which is largely dependent on the function of legal tender conferred on it by law. When, therefore, the demand for gold as money increases with the demonetisation of silver, the growth of population, and the expansion of the production of commodities producible at will, such production being promoted by the progress of science and the opening up of new lands, we have a case of unearned increment, which is, so far, apparently independent of compensating influences. Moreover, the unearned increment in this case is much more extensive than any which arises

*The reader will, I hope, pardon me for not treating the subject of value historically. To have reviewed the various definitions and sub divisions which have been introduced by different writers would have encumbered the paper unnecessarily. It is impossible to draw a hard and fast line between commodities which can be indefinitely multiplied and those which cannot be increased at all, or between commodities on which competition operates and those which are absolute monopolies. In practice the differences are very largely mere differences of degree. The anxiety which has been manifested in South Africa in consequence of the alleged discovery of the new "Wesselton" diamond mine suggests that even diamonds may become, for a time, things practically capable of indefinite multiplication. I have adopted the term "producible at will" as giving a sufficiently simple distinction for the purpose of the paper. Everyone can recognise the difference between the producibleness of commodities like wheat, or woollen, or cotton goods, and of a rare metal like gold.

from a direct increase in the value of land, because an appreciation of the standard legal tender (or, in other words, a fall of prices) not only increases fixed rents in terms of the commodities produced, but all debts whatever, and all interest payable on such debts, and especially on permanent investments; in short, all payments for past services, such as are represented by the National Debt or the existence of the very machinery essential to the life of the State, such as railways, waterworks, and other public and private undertakings. Thus, an appreciation of the standard legal tender not only creates a purely arbitrary unearned increment for the land-holder who has let his land on long leases, but for every bondholder and creditor who can demand payment in terms of the standard metal.

Now, is there anything which tends to counteract an arbitrary appreciation in the exchangeable value of gold as money? Sir Thomas Farrer, adopting the theory of Mr. Henry Dunning Macleod that credit is money or "currency," practically contends that there is. An appreciation of the standard money is the same thing as a fall of general prices; and Sir Thomas Farrer, assuming, for the sake of argument, the truth of the quantitative theory of prices, according to which prices in the long run are governed by the relation between the volume of commodities and the volume of money, submits that the volume of money includes credit as well as gold. "Credit," says Mr. Macleod, "is circulating medium exactly as money is." "Credit," says Sir Thomas Farrer, "is not merely an economy of gold—it takes its place (in the form of bills, &c) as a circulating medium"; and, further, "it is not to gold but to credit that we must look as the immediate regulator of prices" (*What do we Pay With? or, Gold, Credit, and Prices.* By Sir T. H. Farrer, Bart.).

Now a little consideration will, I think, show us that credit is really the monetisation of commodities. The bills

drawn against shipments really represent the commodities; the credits allowed on securities represent commodities in the fixed form, for which the securities stand, such as Brazilian railways. The credits allowed against Consols represent the accumulated assets of the nation. And even accommodation bills, so far as they are in any sense legitimate, may be said to represent potential commodities. Cheques, when not drawn against actual cash deposits, also represent commodities which are monetised, for they are drawn against discounted bills backed by bills-of-lading, which are mere warrants against goods, or they are overdrafts guaranteed by securities representing certain assets. Even in the case of over-drafts against which no securities are actually deposited, the banker, in trusting the solvency of his customer, believes that the credits are utilised for the purchase or holding of commodities. Credits which have not some substantial backing of this kind may be classed with spurious bank notes or false coin. Sir Thomas Farrer's contention, therefore, really is, that instead of bi-metallism (the monetisation of two commodities), what I may describe as a kind of poly-metallism (the monetisation of many commodities) actually exists. This monetisation of commodities is effected, so far as the documents are in terms of gold, by the bankers and other gold capitalists, and it is monetisation in a fixed ratio; for when a bill is drawn for £1,000 against a given shipment of goods, and circulates as credit money, the meaning is that those goods have, for the time being, been monetised in a given ratio to one thousand sovereigns. A bank is a kind of commodity mint; and just as notes issued against an equivalent reserve of gold are gold-notes circulating instead of the gold, so a bill, or other credit form, is a circulating commodity note.

But this circulation is of a very limited kind. The credit money, for instance, does not, generally speaking, diffuse itself amongst the consumers of commodities, and it

does not, in any influence it may have on prices, affect all prices equally. As the French would say, its "liberatory" or paying power is limited: particular bills are known only in particular trades. Moreover, the duration of the liberatory power is brief: for the credit money is liable to periodical demonetisation. Thus, as Mr. Goschen pointed out in his Leeds speech, we were, during the recent Baring crisis, on the brink of a collapse of all British credit, which would have meant the instant demonetisation of all the commodities and securities represented by the credit money afloat, gold remaining as the only commodity which would have retained its paying power. The effect on prices would have been the same as the effect on the gold price of silver of the demonetisation of that metal; the prices of all commodities and securities would have fallen enormously in terms of gold, or, in other words, the value of gold in commodities would have risen enormously, the "unearned increment" of the fortunate holder of gold being proportionately increased. To a certain extent, something like this happens regularly as bills approach maturity, or the date on which the commodities they represent will be demonetised. As the period of commodity demonetisation approaches, the holder of the commodities becomes a more pressing seller, and a seller against gold, just as the German Government became a seller of silver at declining gold prices when it demonetised the white metal. If a bill is drawn in terms of gold, it is, practically, against gold money that the merchant sells his goods, for even if he sells in the first instance for silver rupees, he must re-sell his rupees before he can discharge his debt. I do not deny that the continuance of a volume of credit money, the disappearing portions of which are speedily replaced by fresh bills, and which is never wholly withdrawn, does tend to keep up prices, or to lessen the buying power of gold money; the admission that a ruinous fall of prices would have inevitably followed a

collapse of credit with the downfall of the Baring firm implies this. No doubt the fact that the seller of the demonetised commodities remits other credits in payment of his gold debt, rather than the actual metal, lessens the strain on gold, and, therefore, to some extent controls its value. But, making allowance for these influences, what I wish to point out is that the periodical demonetisation of the commodities represented by particular credits does counteract the influence of credit money on prices. And it has even a very special influence in depressing prices; for the monetisation of commodities by the issue of credit money against them tends to call additional commodities into existence, thus increasing the supply. On the other hand, their demonetisation, on the expiration of the currency of the credit instruments drawn against them, is, practically, according to Sir Thomas Farrer's own argument, a contraction of the currency. Thus we have an expanding currency calling goods into existence, and a contracting currency when the goods come to be sold for gold money. So that the influence of credit in assisting gold as currency, and therefore lowering its value, tends to cease and to leave the gold without a partner in the presence of an enlarged supply of commodities when they are sold. The world is, of course, richer in proportion to the increase of commodities; but clearly in such circumstances the increase of wealth tends to go to the gold owner.

With reference to this point, there is a noteworthy passage in Sir Thomas Farrer's treatise. "If," says Sir Thomas Farrer, "prices of goods fall, not by reason of any change in the measure of value, but by increased abundance of the things sold, what considerations of justice or of convenience are there which call for an alteration of the measure of value?" The reply is, that the measure of value is also the ultimate medium of payment, and if the distribution of commodities is to continue in a given pro-

portion to the relative services rendered, then the measure of value and the medium of payment should be approximately subject to the same increasing influences which affect the quantity of commodities; the ratio between them should remain unchanged. For it is clear that, if the producer has certain payments to make to the creditor class in the standard of value, and, by the exercise of genius, or even increased labour, he so improves his production that the yield is doubled and prices fall proportionately, then a portion of his increased production, greater or less according to the proportion of his debt in the standard to the total value of his production, passes over as unearned increment to the creditor. An equivalent change in the volume or value of the standard, by leaving prices unchanged, would leave the reward of increased or more efficient labour in the hands of the producer without robbing the creditor. We may put it that steady prices are most conducive to equitable distribution. According to Sir Thomas Farrer's contention, the value of the standard is altered by the addition of credit to the volume of gold money; it must therefore be altered by its withdrawal; and both operations are dependent on the interests and convenience of the gold-owning class.

In dealing with this point, Sir Thomas Farrer falls into error in an illustration of the "strange results" which might follow an alteration in the value or quantity of the standard or legal tender commodity proportionate to that of the non-legal tender commodities. "Suppose, for instance," he says, "that the price of labour remains the same, but that the price of all articles consumed by workmen falls in consequence of improvements in production, the effect of lowering the measure of value in accordance with the average of prices would be to diminish money wages, and at the same time, in addition, by raising prices, to diminish real wages." The argument overlooks the fact,

that if wages remained unchanged with falling prices, they would, for the same reason, rise with rising prices under the assumed conditions, and, as a certain portion of the workman's expenditure is of the nature of a fixed charge unaffected by a variation in the measure of values, he would clearly be a gainer.

Again, the influence of credit money on prices is partial and arbitrary: it is not diffused. As I have said, the creation of credit money is in the hands of the capitalist financier, or banker. He is able to monetise any commodity he pleases, and to charge any seignorage he likes for the service. Now, when this power of monetisation is distinctly used for the purpose of advancing prices, it is, as a rule, employed on securities, or on raw materials in the operations known as "corners." The particular articles are monetised at a rising ratio to gold, and so long as the "corner" lasts the operator obtains in exchange for his monetised commodity or bonds a proportionately greater quantity of gold, or of other wealth measured in gold. I am not discussing the utility or justification of these operations; I merely wish to cite unmistakeable illustrations of the fact, that the quantitative influence of credit money on prices, as a partner with gold, does not diffuse itself over labour and commodities generally. In this respect a credit inflation of prices is a very different thing from an advance of prices due to an increase in the volume of metallic money of full liberatory power throughout the world, as such money, in accordance with the natural economic laws on which the whole science is based, does tend to search out all commodities and all labour throughout the world and affect them proportionately.

Finally, the volume of credit money depends on the volume of gold under a gold monometallic system, or, to speak in more general terms, on the volume of money of full, universal, and permanent liberatory power. The precise relation cannot be stated; it is sufficient to say that there

is a critical point when the volume of credit money feels the pull of real money, and its elasticity is checked. A familiar demonstration of this was the borrowing of French and Russian gold by the Bank of England during the recent Baring crisis in order to prevent a contraction of credit money. There is a proportion of reserve which bankers, in practice, find it necessary to hold, and, therefore, admitting that credit money does substitute gold and affect general prices as an effective addition to the volume of money, its own volume, and therefore its effect on prices, is still conditioned by the abundance or scarcity of gold. The relation varies according to the facilities of communication and transport, or according to the rapidity of circulation or greater intensiveness in the working of gold, for it is not denied that an increase in the number of exchanges effected by a given piece of gold in a given time may be equivalent in its effect on prices to an increase in the quantity of gold. But, so far as the theory goes, it is sufficient for those who contend that the fall of general prices has been due to a scarcity of gold, resulting from diminished out-put from the mines and increased demand for the metal as money and as the basis of credit in consequence of the demonetisation of silver, to establish the fact, that the volume of credit money has a relation to the volume of metallic money of continuous and international liberatory power. This being admitted, the question becomes simply whether the vast diminution in the volume of the ultimate measure of value, brought about by the establishment of gold mono-metallism, has been made good by the more intensive working of the units composing that volume, due allowance being made for the increase of population and the vast increase of commodities which, in themselves, demand increased distributive work from those units. What I wish to bring out clearly is that, granted a relative absolute scarcity of gold, the influence of credit in prevent-

ing a fall of prices is itself checked by the very scarcity of gold which is the primary condition inducing the fall. Credit money does not imply the effective action of the principle of compensation; because credit money does not expand as gold money contracts, but, on the contrary, other things remaining equal, tends to contract in some ratio with the contraction of gold money. In this respect, though I have spoken of credit money as a kind of poly-metallism, it is fundamentally different from true bi-metallism based on the bestowal of full liberatory power on the two precious metals; because, if the theory be sound, true bi-metallism implies the effective action of the principle of compensation under the assumed conditions, a monetary strain on one metal being instantly and automatically counteracted by a corresponding inflow of the other. The precious metals would be equal and competing monies, permanently exercising their liberatory functions in their own right independently; whereas, credit money has, at the best, only a temporary currency, and its power is to some extent derivatory from the full legal tender, gold, to which it is, therefore, subservient.

II.

To summarise, we have seen that circulating credit implies the monetisation of commodities in a fixed ratio, and so far resembles bi-metallism as to be describable as poly-metallism; that within certain limits it affects prices, according to the quantitative theory, by proportionately increasing the volume of money for the time being; that its circulation is, however, limited—a circumstance due to the fact that it is not legal tender—and that it does not circulate, for instance, amongst consumers of commodities; that the commodities represented are demonetised, not merely in periods of panic when credit collapses, but periodically as the instruments of credit approach maturity; that the commodities have then

to be sold against international legal tender money, or effectively, gold, under conditions analogous to a contraction of the currency as regards the prices realised.

It will not be supposed that, in pointing out these differences between credit-money and a permanently monetised commodity like gold, with the attribute of international legal tender, I am condemning credit money. Circulating credit fulfils a very important function in the movement of commodities, and its growth and use are not merely a demonstration of a true economic origin, but also, incidentally, imply the recognition by mankind of the necessity for an extension of monetisation beyond one rare commodity, such as gold.

When, however, credit-money is put forward as being practically efficient in remedying the defects of an in-elastic supply of real money, which is at once a standard of value and currency, it becomes important to define the differences, in order that we may arrived at a truly scientific remedy. Now, in pursuing the comparison between credit-money and real money, and more especially with reference to the influence of monetary law on the distribution of wealth, I have found it more and more necessary to define some ideal form of money, or at least to adopt some abstract term which shall be held to be representative of those powers which a perfect money, or, if I may so express it, distributor of wealth, should possess. In connection with the currency controversy, and particularly in pursuing the present series of thoughts, I have felt a difficulty similar to that which Professor Faraday experienced in constructing his theory of electro-chemical decomposition, that of using terms which were already current with a certain accepted meaning. In order to avoid "confusion and circumlocution," and "for the sake of greater precision of expression," the great physicist invented a new terminology. Some of the terms of electrical science previously employed were, he said, "much too significant" for the use

to which he would have to put them, and, he added, "through a very imperceptible, but still very dangerous, because continual, influence, they do great injury to science by contracting and limiting the habitual views of those engaged in it." Now so many, and more or less restricted, meanings have been acquired in the minds of different persons by the words "money," "coin," "currency," "standard," and so on, that I have at times found it quite impossible to convey my meaning as an advocate of *one* standard consisting of the *two* metals, gold and silver, minted in a fixed ratio, when using terms which my opponents have persisted in interpreting merely according to their own conventional habit. A very great amount of misunderstanding arises from this tyrannous influence of words. I have, therefore, been bold enough to borrow the term *ion* from my distinguished relative's electrolytical terminology, and propose to speak of monetary *ions* instead of currency, or standard, or legal tender, as a term including the attributes of all these things. In the "Experimental Researches in Electricity" (Seventh Series), *ions* are defined as those bodies which "can pass" to the electrodes. The monetary *ion*, then, is that which "can pass," and in the act of passing distributes wealth. I am the more in favour of this term because my predecessor tells us that, in his conception of electrolysis, "the determining force, is *not* at the poles, but *within* the body under decomposition." And my idea of a monetary *ion* is that of a something which, though deriving its liberatory or paying power from the quality of legal tender conferred on it by the Legislature—as the chemical *ion* is liberated by the electrolytical arrangement—yet contains its *value* or determining force within itself.* As in the case of the electro-

*I hope this assumption of inherent value will be allowed to pass for the purpose of the argument. Those economists who deny the labour basis of value may interpret it as value other than mere *just* value.

lytical *ion*, my perfect monetary *ion* should have an invarying quantity of force; that is, it should always be in exactly the same exchangeable relation to commodities, which would then be the corresponding *ions* passing in the opposite direction; unit for unit their respective values should be approximately as invariable as the force of electrolytical anions and cations. In developing his electrolytical theory, Michael Faraday found it desirable to have a "natural standard" of electric direction, and he took the earth as that standard. In the present case I take, with Adam Smith, labour as the natural determining standard in relation to all questions involved in the consideration of monetary *ions*; the labour being estimated quantitatively acccording to its efficiency. Thus a monetary *ion* should always bear the same proportionate relation to labour that the commodity *ions* produced by labour bore to labour. Increase of efficiency, as a result of scientific discovery or the application of natural power, would increase the commodity *ions* produced by a given labourer in a given time; this, in my view, would be an increase in the quantity of labour. Michael Faraday points out that any change in our views of the nature of electricity and electrical action must affect equally his natural standard and the decomposing substances. Pursuing the analogy which I am setting up in order to make my views clear, my monetary *ions*, deriving their force from labour, should be affected by the change which affected the commodity *ions*; that is the more efficient labour, producing an increased quantity of commodity *ions*, should command a proportionately increased quantity of monetary *ions*, the relation between the commodity *ions* and the monetary *ions* (or the price) remaining undisturbed. I pointed out in my former paper (*Proceedings*, Vol. XXVI., 1886–7) that labour-saving discoveries tend to extend their influence to the production of all commodities, the efficiency of all labour being proportionately increased. The monetary *ions* must not be

exempt from the influence of this tendency, if the assumed steadiness of relation to the commodity *ions* is to be maintained.

In various writings on the subject Sir Thomas Farrer has put forward the argument that gold has not appreciated in value, but that commodities have fallen because their production has been increased. As an illustration, he cites (*What we Pay With*) an apple tree which suddenly produces 24 apples instead of 12, the labour, or human effort of cultivation or production, remaining the same. Now it is quite clear that, in such a case, assuming that the monetary *ions* remained unaffected in their quantity, and that, therefore, the price of apples fell one half, the landlord and other fixed creditors payable in monetary *ions* would receive the equivalent of double the number of apples formerly received by them ; and, perhaps, if the increment were as accidental as Sir Thomas Farrer assumes, the creditors might be as well entitled to it as the labourer. But a general increase of commodities implied in a general fall of prices is not due to such accidental causes ; it depends either on an increase of labour or on the increased efficiency of labour ; and if labour is to get the full reward of its increase in quantity or efficiency it is to me perfectly clear that the relative value of the monetary ions in which the fixed charges are paid must remain unchanged. This can only be by a proportionate increase in their quantity under the action of the same law which affects commodities, by which labour seeks the most remunerative field of production, or in their efficiency by rapidity of exchange increased by a highly organised system of banking, which means, practically, the same result as an addition to quantity. If commodities generally increase, and the monetary *ions* remain practically unchanged in quantity, then a fall of prices is an appreciation of the monetary *ions*. Their labour cost of production

has remained unchanged, which means that the efficiency of the labour employed in their production has not increased, as in the case of all other labour. It also means that there has been no diminution in the cost of production in consequence of the cheapening of every material which enters into that cost, which is an absurdity unless the labour has become correspondingly less efficient. This, of course, might happen in the case of gold, for instance, through the diminished richness or greater depth of the mines. In any case, it is clear that, either through what John Stuart Mill calls a "natural monopoly," or through an artificial monopoly, the exchangeable value of the monetary *ions* having increased to exactly the extent of the fall of prices, this value has received an addition which may or may not be an unearned increment in the case of the producer, but is certainly an unearned increment in the case of all creditors. They are then no longer perfect monetary *ions*. Sir Thomas Farrer's notion of a standard money which can remain stationary, while all other things are increasing in quantity, and that, therefore, it is the "other things" which have depreciated, and not the standard which has appreciated, is illusory. The medium of payment in such a case has been sheltered from the influences affecting all other commodities, and it has received an arbitrary addition to its exchanging power. It ought to be considered, therefore, as great an anomaly in economics as an electrolytical *ion* with a variable exchanging power would be in physics.

I do not go so far as to suggest that any commodity can be named which will be absolutely unchangeable in value relation to other things. Still there are commodities which, as monetary *ions*, would, *on the average*, bear a steady relation to most other commodities. Adam Smith perceived this when he said that the exchangeable value of corn-rents would be likely to be more steady from century to century, though

more variable from year to year, than money (that is gold or silver) rents. Ricardo was also evidently influenced by a similar thought when he wrote to Malthus on October 17th, 1815, "I think with you, that, on the whole, silver would be a better standard than gold" (*Letters of David Ricardo to Thomas Robert Malthus, 1810 to 1825.* Letter XXXVIII). Wheat owes its relative steadiness, in terms of other commodities, to the fact that it is one of the class of commodities producible at will, but it is liable to sudden temporary variations in exchangeable value, in consequence of natural causes, such as failures of the crops. For this reason, and also because of its bulk, its perishable nature, and other conditions, on which I need not dwell, wheat and many other commodities, however steady they might be on the average, are not suitable for the payment of debts, for storing value, or for easy world-wide circulation, functions which must be fulfilled by true monetary *ions*.

It would be going over old ground to proceed to show how peculiarly suitable to these several purposes the precious metals are by reason of their peculiar qualities as metals. But when we consider their special appropriateness as monetary *ions*, it is necessary to call attention to the fact that their suitableness in contradistinction to credit-money rests on the fact that they have a force within themselves. Now that natural force is derived from the labour spent in their production and their utility as metals. There is a good deal of philosophy in a remark made by a delegate at the Canadian Trades and Labour Congress held in London, Ontario, in 1888. A proposal was brought forward that in future the Dominion Government should no longer borrow money for the construction of public works, but should meet the cost by an issue of legal tender notes. Mr. A. F. Jury, in opposing the motion, observed pithily that he did not believe in exchanging the product of his labour

for money which did not represent the labour of some other man. The fact is, that payment by Government notes would be merely a monetising of the labour of the men embodied in the public works, and the exchange would have to be effected afterwards for what it was worth. The mere monetising of a given construction or commodity does not imply exchange; because if there were no other labourers or no other commodities in the world, the notes representing their own work merely might still be paid to the labourers; and such notes would not be convertible in the product of the particular labour monetised, and would not therefore have the inherent force of true monetary *ions*.*

The payment of gold and silver money, however, does involve exchange, because such money is in itself other labour and other consumption. A piece of gold or silver now circulating may have been produced in the time of Solomon, but it still replaces certain commodities definitely consumed in its production; it implies a certain vacuum created which it has itself filled, a certain quantity of labour-energy converted into the latent form; and in every exchange in which it takes part the void, so to speak, created by its movement is filled by an equivalent modicum of labour-energy represented by some other commodity or service.

But if any given monetary *ion* is to remain in practically

* Mr. H. D. Macleod (*Theory of Credit*, Vol. II., Part 2) urges that the real weakness of what he calls "Lawism" (the paper money theory of Law) is the idea that money "represents" commodities. Is not the real weakness of "Lawism" the fact that notes issued against land, for instance, do not effectively represent commodities, being inconvertible in the commodity against which they are issued? The holder of a particular note under Law's scheme could not redeem it in the particular fragment of land represented, nor would that particular fragment be capable of circulation or have any value or utility if exchanged. Notes, or credit instruments in any form, are only so far sound as they effectively represent or are convertible into commodities or services having the full value in exchange expressed by the denomination of the particular note or instrument.

unchanged relation as regards its inherent force with all commodity *ions*; in other words, if it is to remain a perfectly steady standard of value, it must not derive an increment of value merely from the bestowal upon it of the quality of legal tender by the Legislature. The bestowal upon any one commodity, not capable of indefinite multiplication, of the function of legal tender, does undoubtedly tend to increase its value by giving it an additional utility; my view is that, theoretically, the Legislative effect should go no further than the setting free of the *ion*.* In proportion as there is any effect beyond this, that effect is an artificial interference with natural economics, and, therefore, necessarily, with the equitable distribution of wealth involved in the free play of natural laws. A theoretically invariable monetary *ion* may be unattainable in practice, but in examining the conditions which interfere with its attainment we may at least see how to realise the ideal *ion* approximately, on the average.

Now, one way in which the value of a commodity is increased by the bestowal upon it of the function of legal tender is by converting the producer or holder instantly into a buyer. "The situation of the producers of gold," says M. Cernuschi, truly, "is quite different to that of the producers of any kind of merchandise. The producer of any kind of merchandise does not know how his profit and loss stands until he has realised in gold, that is to say, sold his merchandise for money. The producer of gold himself directly produces

* In his very thoughtful little book, entitled "Bi metallism; or, a Fixed Ratio between the Two Metals, Gold and Silver," recently published, Mr. Councillor W. T. Rothwell, of Manchester, speaks of the "money power" as a property which can be added to or taken from gold or silver; any commodity invested with this property being merely "the raw material out of which money is manufactured." It will be seen, I hope, from what I have written above, that, according to my view, in a perfect monetary system, this "money power" should not be an addition in the sense of an added value, but rather the mere conversion of the natural economic energy of the material from the potential to the kinetic form.

money. His realisation is ready made." And again: "The producer of any kind of merchandise is not always able to dispose of it. The market may be glutted. There may be no outlet. Things happen quite otherwise with the producer of gold. Whatever the quantity produced, the gold has a full right to enter into circulation. All the grammes of new gold are exactly equal to all the grammes of old gold. All have the same power. The old metal cannot bar the way to the new metal."

It is sometimes argued that each party to an exchange is at the same time both a buyer and a seller. But we know that, in practice, the real buyer, the man in possession of legal tender money, has a balance of advantages over the man with commodities which are not legal tender, and if the number of the selling-class is increased, the greater is his advantage. As I have already pointed out, it is in consequence of this fact that credit money fails to act as a permanent check on any arbitrary increase in the buying power of gold money; because the holder of credit-money sooner or later becomes a seller of his demonetised commodities. In much the same way the demonetisation of silver has increased the number of sellers proportionately to buyers, and has thus brought about the greater part of that depression of prices which Sir Thomas Farrer supposes to be entirely due to other causes. Prior to 1873, the Lancashire shipper of goods to the East really became added to the buying class the instant he had sold his goods for silver, which was practically international money equally with gold, in consequence of the operation of the French bi-metallic monetary law. At the present time, after selling his goods for silver, he becomes a mere seller of silver. Thus he appears as a seller twice over, the number of the transactions against gold being proportionately increased. The equation is thus enormously disturbed. It has been strangely overlooked that the depression of the

price of silver in the London market and of the Eastern exchanges is not due alone to the small supply of American silver which finds its way to London, but is also attributable to the potential offer for sale there of £50,000,000 of silver, against which British goods are every year sold in the East. The silver is really not offered for sale; but there is no limit to the decline in the Eastern exchange, except the price at which the rupee could be sold as demonetised metal if actually sent to London.

It will, I know, be said that the influence of this potential offer of Eastern silver money as a demonetised commodity is off-set by the demand of the Mincing Lane produce importers, who require the same silver as money to pay for Indian produce. But a more searching examination of the actual operations will show that this is not fully so. Let us assume that last autumn the coined rupees of India had become full and permanent international legal tender at the exchange rate temporarily quoted—say 1s. 9d.,—the India mints remaining open. In that case the Lancashire exporter, rather than accept a lower price—allowance being made for the cost of shipping and insuring the specie—for bills convertible into rupees, would bring home the coin for deposit in the banks and for the payment of his liabilities, and it would be absorbed into the general circulation, or rest as a cash balance in the banks; and the Indian Government would also pay the home charges with rupees rather than sell Council drafts. On the other hand, the Mincing Lane importer, so long as there was any uncoined silver in the market to be had at a sufficiently lower price than the drafts to off-set the cost of shipping and insuring the metal to India, would buy such silver to discharge his liabilities in India. Now the stock of silver in London is always relatively insignificant; even the stock in New York, accumulated under quite exceptional conditions by speculative operations prior to the passing

of the American Silver Act of July 14, 1890, and consisting partly of coined metal drawn from the currencies of the Central and South American States, did not exceed 13,000,000 ounces at the maximum, and at the present time is reported less than 6,000,000 ounces; that is, there has been a floating surplus stock of from £1,000,000 to, at the outside, £2,500,000 worth of silver in New York. But the Mincing Lane men alone would require from £34,000,000 to £40,000,000 of silver to pay for their own imports, to say nothing of the demands for the payment of Indian exports to other parts of the world, amounting in all to about £90,000,000 in round figures. Even with the aid of the Council drafts in settling the balance of trade there has been an average export of £7,500,000 of silver per annum to the East during the last ten years *via* Southampton, Venice, and Marseilles. There would, therefore, be far more buyers of silver than sellers, a demand vastly beyond the available surplus of uncoined silver; nay more, the demand would greatly exceed the total production of new silver from all the mines in the world. The price would, therefore, necessarily rise until it became worth while to take the rupees from the banks for shipment back to India, and, this stage being reached, the Lancashire exporter, the Indian Government, and the Mincing Lane importer, would of course proceed to save the cost of moving the rupees from India to London, and from London to India, by selling and buying drafts on the basis of the par value of the rupee. The only difference from the existing conditions would be that the Lancashire exporters and the India Council would no longer be practically forced sellers of rupees in a market where they are demonetised, any more than the holder of Australian sovereigns is at present a forced seller; and the Mincing Lane man would no longer be in the position of the buyer of a commodity which is of no use to the seller.

It is not difficult to demonstrate the soundness of this argument. If the silver bullion market is not depressed by the potential offer of the vast stock of coined silver to the silversmiths of London, but only by the surplus stock of newly-produced silver, then, as I pointed out to Mr. Goschen during the conference at the Treasury on February 11th, 1891, it would have paid the Indian Government to have bought up the American stock of one or two millions' worth, and thrown it into the sea, for the loss by exchange to the Indian Government in consequence of the decline has already exceeded the value of that stock.

But this "depression" of demonetised silver is really the same thing as an appreciation of gold, and it is for the same reason common to all commodities in relation to gold. Admitting then that gold money is artificially appreciated, in consequence of the special power conferred on it by its practical adoption as the sole international legal tender money, we have to devise some legal arrangement which would counteract this influence, in order to obtain true monetary *ions*, such as I have defined. The sufficiently approximate solution of the problem will be found in controlling the gold *ion* by placing it in definite monetary relation with a suitably representative commodity *ion*—silver. I speak of silver as a representative commodity, because, during the trying period since the closing of the French mint, it has fully justified Ricardo's opinion as to its relative steadiness of exchangeable value, and its submission to what I have referred to as the economic law tending to maintain steadiness of mutual exchangeable value between all commodities producible at will. This will be seen from a glance at the following table, showing the buying power of silver and gold respectively during the last 20 years (embracing the period of the demonetisation of silver) and at the present time in terms of wheat :—

Table showing weights of silver and gold respectively which would exchange for one quarter of wheat in the undermentioned years, calculated according to the average prices in the London market in each year, gold being taken at the Bank of England price of £3. 17s. 9d. throughout.

Year.	Average Gold price of silver per oz.	Gazette average gold price of wheat per qr.	Weight of silver to 1 qtr. of wheat.	Weight of gold to 1 qtr. of wheat.
	d.			
1871	60½	57/-	11·3058 oz.	0·7331 oz.
1872	60 5/16	57/-	11·3409	0·7331
1873	59¼	59/-	11·9494	0·7588
1874	58 5/16	56/-	11·5241	0·7202
1875	56⅞	45/2	9·5297	0·5809
1876	52¾	46/2	10·5024	0·5938
1877	54 13/16	56/9	12·4242	0·7299
1878	52 9/16	46/5	10·5968	0·5970
1879	51¼	43/10	10·2634	0·5638
1880	52¼	44/4	10·1812	0·5702
1881	51 1/16	45/4	10·5248	0·5831
1882	51⅝	45/1	10·4794	0·5798
1883	50 9/16	41/7	9·8689	0·5348
1884	50⅝	35/8	8·4543	0·4587
1885	48⅝	32/10	8·1028	0·4223
1886	45⅜	31/-	8·1983	0·3987
1887	44⅝	32/6	8·7394	0·4180
1888	42⅞	31/10	8·9096	0·4094
1889	42 1/16	29/9	8·3631	0·3826
1890	47 1/16	31/9	7·9895	0·4083
1891 (March 31)	44⅝	34/5	9·2549	0·4426

I have taken wheat as the standard, in accordance with Adam Smith's opinion that corn rents would be more steady from century to century than money rents, and because wheat, being a primary necessary of life, producible at will, is perhaps more than any other commodity subject to the law of supply and demand, the acreage placed under wheat varying according as it is a more or less profitable crop. From year to year, of course, the exchange value of

wheat has varied according as the crops have been good or bad; but it will be seen from the table, that, compared with gold, the value of silver in wheat has been remarkably steady. Both metals have appreciated, a fact which may seem rather startling to those who talk of silver as a depreciated and rejected metal. But, whereas the appreciation of silver, if we take last year's silver price of wheat and compare it with the first year in the table, has been only about 29 per cent., the appreciation of gold has been upwards of 44 per cent. Last year was, however, an exceptional year, silver having been enhanced temporarily, by the American speculative operations, without any corresponding possible influence on general prices resulting from an addition to the quantity of money consequent on the monetisation of the silver purchased under the new Silver Act, which could, of course, only affect the prices of commodities gradually and after a certain lapse of time, as the silver or the representative Treasury notes got into circulation. If we take present prices as more representative, we find that silver shows an appreciation of 18 per cent only, against an appreciation of 40 per cent in gold. But if we compare this year with 1875, which introduces us to a period when the changes in the cost of transport due to the opening of the Suez Canal, the extension of railways in India and the United States, and the vast improvements in marine engineering have combined to cheapen commodities generally, we find still more remarkable steadiness. Silver has still appreciated, and that is explainable, as the improvements in transport to which I have referred must be expected to tell more in the case of bulky commodities, like wheat, than in the case of rare and precious metals; in other words, some fall of prices under any suitable metallic standard would naturally follow such improvements. But, comparing the price of silver to-day with 1875, we find an appreciation in terms of wheat of

less than 3 per cent., against an appreciation of nearly 24 per cent., in gold.

Now if gold has appreciated in consequence of its artificial monopoly privilege as a legal tender, it has also appreciated because it has more the character of a natural monopoly than silver, its production being proportionately more precarious. This will be apparent from the following table, showing the world's production of the two precious metals during each of the last twenty years:—

Production of silver and gold throughout the world.

Year.	Silver.	Gold.
	oz.	oz.
1871 } Av. 1872 } per 1873 } ann.	63,267,000	5,264,000
1874	55,300,000	4,879,000
1875	62,262,000	5,242,000
1876	67,753,000	5,575,000
1877	62,648,000	6,129,000
1878	73,476,000	6,397,000
1879	74,250,000	5,860,000
1880	74,791,000	5,725,000
1881	78,890,000	5,537,000
1882	88,470,000	5,483,000
1883	89,177,000	5,129,000
1884	81,597,000	5,467,000
1885	91,652,000	5,827,000
1886	93,276,000	5,698,000
1887	96,189,000	5,661,000
1888	110,086,000	5,910,000
1889	126,000,000	6,388,000
1890	130,650,000	6,675,000

From this table we see that, while the annual production of silver has steadily increased year by year, and is now about double what it was twenty years ago, the out-put of gold has tended to remain stationary, and although some expansion has occurred during the last three years, in consequence of

the opening up of the South African gold fields, the total for last year is only 27 per cent more than in 1871, while the increase in the out-put of silver is upwards of 100 per cent. The fact, that though the out-put of silver is now double what it was even in 1875, the metal shows an appreciation of 3 per cent in value, while, with an increase of about 27½ per cent in the out-put of gold against the same year, its buying power has risen 24 per cent, is a justification of Ricardo's prediction of the relative steadiness of silver. On the other hand, the fact that silver has appreciated in terms of commodities notwithstanding the great increase in the out-put, is a sufficient answer to the "wheel-barrow" argument that its re-monetisation would imply a vast rise of prices, a supposition which was effectively met in the following passage by Ricardo eighty years ago: "Coffee, sugar, and indigo are commodities for which, although there would be an increased use if they were to sink much in value, still, as they are not applicable to a great variety of new purposes, the demand would necessarily be limited; not so with gold and silver. These metals exist in a degree of scarcity, and are applicable to a great variety of *new* uses; the fall in their price in consequence of augmented quantity would always be checked, not only by an increased demand for those purposes to which they had before been applied, but to the want of them for entirely new employments."

The facts also afford a sufficient answer to Jevons's contention that the monetisation of silver in a fixed ratio to gold would result in our getting to silver money, gold disappearing from circulation, and that we should thus retrograde from a more convenient to a less convenient form of currency. If this were true, the answer is, that the tendency is to substitute for metal the most convenient form of currency, paper notes or certificates representing the metal. It is to this method that economists look forward, and it is in progress in America, and in the development of our own cheque system.

Its latest expression is Mr. Goschen's proposal to issue one pound and ten shilling notes. In the passage already quoted, Ricardo foresaw this, and says, "I think with you that, on the whole, silver would be a better standard than gold, particularly if paper only were used. All objections against its greater bulk would be removed" (*Letters to Malthus*). But it is inconceivable that gold could disappear from circulation; its major use is as money; and the relatively small consumption for the arts, which falls considerably short of an annual production of only £21,000,000, could as little expand so as to absorb the £700,000,000 used as currency, as the consumption of iron for nails could deprive the market of the supplies of that metal required for railway and engineering purposes, and lead to the sale of the railway lines themselves to the manufacturers of tacks. The annual out-put of gold from paying mines would not be checked by a decline in its exchange value as money due to the remonetisation of silver beyond any decline which—for the reasons given by Ricardo—is at all likely to be seen. And even if its production were likely to be checked by a special increase in the cost of production due to increasing rarity, it is contrary to all sound economic theory to encourage its production by the taxation of the producers of all other commodities, which is what the continuance of its monopoly value as money implies. The influence of an international monetary law declaring both metals legal tender in a fixed ratio would therefore be simply to control the artificial enhancement of the value of gold due to the exclusive currency power conferred on it legislatively. In claiming for credit money this utility, Sir Thomas Farrer practically admits the danger of exclusive dependence on gold, and sees a remedy in what I have described as a kind of temporary poly-metallism. I have shown that such a system not only fails to remedy the admitted evils, but, under given circumstances, tends to

increase them. I advocate the permanent international monetisation of the two precious metals as a remedy based on the same principle, but free from the defects, and automatic in its action. Such an arrangement would not interfere with the function of credit money; on the contrary, by steadying prices, it would increase the steadiness of credit. It would in no sense interfere with the movement of the gold *ion* except to the extent of regulating it; a free path would be allowed to it, but it would be, so to speak, a mean free path; instead of being liable, as at present, to fly off into space, it would swing in a certain steady relation, on the average, to commodity *ions* in general.

I feel that I, perhaps, owe an apology to the Society for bringing before it these researches in the domain of economics. It has been the glory of the Society, however, to lay the foundation of that sanitation which is doing so much to improve the health-conditions of the masses, and to produce two great teachers, Dalton and Joule, whose discoveries have vastly increased the efficiency of the labourer, by increasing his use of the forces of nature. It will be not less honourable to the Society, to encourage inquiries tending to promote the equitable distribution of the wealth hus produced.

On the action of different Metals, Metallic Salts, Acids, and Oxidising Agents on India-rubber. By William Thomson, F.R.S.Ed., etc., and Frederick Lewis.

(*Received April 20th, 1891.*)

A few years ago one of us studied the influence of different oily and greasy matters on india-rubber. (*Journal of the Soc. of Chemical Industry*, 29th December, 1885), and at the last meeting of the British Association in Leeds we called attention to the distinctive effect which both metallic copper and all the salts of copper exercised on india-rubber. In the present paper we have carried these experiments further, with a view of obtaining more accurate information as to the effect of copper and its salts, and also that of other metals and their salts, and other agents, on india-rubber.

The method we adopted was to take a fine sheet of india-rubber spread on paper and vulcanized by the cold process with a mixture of chloride of sulphur dissolved in bisulphide of carbon. By this arrangement it was easy to tell the effect of different substances on the rubber; on breaking the paper between the fingers the fine sheet of caoutchouc being left free so that it could be stretched, and a fair idea obtained as to whether its elastic properties had been damaged.

Action of Metals on Rubber.

The first series of experiments was made with different metals reduced, by means of a file, to a fine state of

division, the file employed being first thoroughly cleansed, and then washed with ether, to remove any oily or greasy matters from it. Small pieces of 3 inches square were cut from a large piece of the above-mentioned fine sheet pure Para rubber, and thin layers of the filings of the different metals were spread over about 1½ inches square of the centre. These were then placed together in an incubator, kept constantly at a temperature of 140° Fah. by means of a thermostat, night and day, on glass shelves, and every day the positions of the pieces so treated were altered, so that those in the middle were placed nearer the sides, which we thought might possibly communicate more heat than might be received in the middle. After ten days the rubber on each square was tested in the manner above indicated. This series of experiments was repeated, and the following results were obtained :—

One of the metals had a destructive effect on rubber far beyond any of the others, and that was copper. As compared with copper the following metals had a comparatively slight effect, although they exercised an injurious influence. They are given in the order of the injurious influence they exercised :—

1. Platinum.
2. Palladium.
3. Aluminium.
4. Lead.

The following metals were tried, and found to have no effect whatever :—

Magnesium.
Zinc.
Cadmium.
Cobalt.
Nickel.
Iron.
Chromium.
Tin.
Arsenic.
Antimony.
Bismuth.
Silver.
Gold.

small square sheets of the fine sheet rubber, adhering to paper, and painted one with a solution containing 10 per cent of sulphate of copper. On weighing the amount applied to the rubber it was found to be equivalent to 3·84 grains of crystallised sulphate of copper per square foot. This solution was then diluted with its own bulk of distilled water and a second sheet painted with the diluted solution. This second solution was again diluted with its own bulk of water, and a third sheet painted with it, and so on. There were thus prepared 6 pieces, containing the following quantities of copper salt per square foot of thin sheet rubber :—

	Grains of Sulphate of Copper ($CuSO_4 5H_2O$).	Equal to grains of Copper Oxide (CuO).
Sheet (*a*)	3·840	1·218
(*b*)	1·920	0·609
(*c*)	0·960	0·305
(*d*)	0·480	0·153
(*e*)	0·240	0·076
(*f*)	0·120	0·038
(*g*)	without copper.	

All these pieces were placed in the incubator at 140° Fah. for 9 days, when it was found that the sample (*f*) which contained the smallest quantity of copper, had entirely lost its elasticity and become quite rotten, whilst the piece (*g*), which contained no copper, was perfectly sound ; on examining the others they were all found to have entirely lost their elasticity, and to be hardened exactly in proportion to the quantity of copper salt placed upon their surfaces (*a*) being the hardest. It is, therefore, evident that an extremely small quantity of a copper salt has a highly injurious influence on rubber with which it comes into

intimate contact. In speaking on this subject to Mr. Thomas Rowley, of Manchester, he informed one of us that when he was an india-rubber manufacturer he had proofed large quantities of cloth with rubber, and had a book in which he kept samples of all he produced, many of which were now 15 years old. It struck us that it would be interesting to find whether any of the cloths which had been so proofed, and which had remained good for so long, contained copper, and Mr. Rowley very kindly placed his pattern books at our disposal. These patterns were arranged in numbers, describing the nature of the cloth and kind of proof, etc., and dates. We selected 7 samples, all of which, except one, had been steam vulcanized (*i.e.*), sulphur had been mixed with the rubber composition before proofing, and the combination between the two brought about by heating with steam afterwards. These patterns were perfectly sound, although about 16 years old.

We also selected one pattern of a brown cloth, in which the rubber proofing was decomposed and hardened, and which broke on the cloth being folded or bent. The following is the list of the samples taken:

Private Numbers.	*Date.*	*Description.*	*Results of Analysis*	*Condition in January, 1881.*
No. 110	19 Nov., 1874	Black alpaca.	copper absent	good
,, 222	18 Jany., 1875	Black alpaca.	,,	,,
,, 252	22 ,, ,,	Black Paramatta.	,,	,,
,, 411	2 April, ,,	Blue black Paramatta.	,,	,,
,, —	7 May, ,,	Black fine sheeting (cold vulcanized).	,,	,,
,, 982	28 Aug., ,,	Brown fine sheeting.	,,	,,
,, 1150	24 Sept., ,,	Drab stout twill (black proofing).	,,	,,
,, 638	25 June, ,,	Brown cambric (black proofing).	trace	quite decomposed and hard.

All these samples were steam-vulcanized, except the

one marked 7th May, 1875, which was cold-vulcanized with chloride of sulphur dissolved in bisulphide of carbon.

We carefully tested the whole of these for copper, and found that all those which were quite sound were perfectly free from it, whilst the sample which had become hard contained a trace of that metal. It appeared, therefore, that this trace was sufficient to bring about the complete destruction of the rubber after a number of years.

It may be well to give, as follow, the results of a series of experiments and analyses of some cloths, the rubber proofing on which was found to be destroyed within a few weeks or months after they were proofed. We pasted together, end to end, 19 samples of cloth, taken promiscuously, in one long line, and had the whole of them cut along the line into five equal parts. Each line of samples was then covered with a continuous sheet of different india-rubber mixtures, and one with pure Para rubber. Strips of each series were cut along the whole line, and then were looped and fixed so as to hang from stretched threads in the incubator kept constantly at a temperature of 150° Fah. They were examined from time to time, but, finally, after 25 days, they were removed, and their condition noted; and, simultaneously, the analyses of unproofed pieces of the same cloths were made to find whether they contained copper, and the quantity of copper was estimated in some of them; the quantities of oily or greasy matters present were also estimated. The following table gives the results of the observations and analyses, and shows that the rubber remained good in all the samples of cloth which were free from copper, whilst it was more or less seriously damaged in all the samples which contained copper, and, still further, the damage sustained was, as nearly as could be observed, in direct proportion to the quantity of copper present:—

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We also selected one pattern of a brown cloth, in which the rubber proofing was decomposed and hardened, and which broke on the cloth being folded or bent. The following is the list of the samples taken:

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,, —	7 May, ,,	Black fine sheeting (cold vulcanized).	,,	,,
,, 982	28 Aug., ,,	Brown fine sheeting.	,,	,,
,, 1150	24 Sep., ,,	Drab stout twill (black proofing).	,,	,,
,, 638	25 June, ,,	Brown cambric (black proofing).	trace	quite decomposed and hard.

All these samples were steam-vulcanized, except the

being left in its original condition, one having all the oily and greasy matters removed, and the third having both oily and greasy matters and copper removed; these were again joined in a line to a piece of grey cloth in its original condition, and to a piece of the same from which the oily and greasy matters were removed. It was, of course, unnecessary to use a third piece of this cloth, as it was free from any trace of copper. The eight pieces thus arranged in one line were divided along the line into two parts; one was covered with a continuous sheet of pure Para india-rubber, the other piece was covered with a rubber composition. Both were vulcanized by the cold process, and afterwards arranged in loops, and hung in an incubator at 140° Fah. for eight days. After that time the rubber on both pieces of grey cloth and the two pieces of black cloth, from which both grease and copper had been removed (in both series), was found to be perfectly sound, whilst the rubber on the two black cloths in their original condition, and on the two from which the oily and greasy matters had been removed, but in which the copper remained, were completely destroyed, the effect of the oil and grease in contact with the copper. (Some of the copper contained in cloth is usually found in solution in the oily or greasy matters also present). The effect is to reduce the rubber to the condition of a soft sticky substance, resembling grease in consistency, and to this condition the proofing is soon brought when the oily matter present in copper mordanted cloths exists in considerable quantity. The mixture thus produced is often absorbed into the fibre of the cloth, leaving it in a somewhat limp and sticky condition; when, however, the oily and greasy matters are removed, the rubber simply becomes hard. It is curious, therefore, to find that the presence of copper, even when oily and greasy matters are absent, is almost as destructive to the rubber, on rubber

Description of Cloth.	*Per Cent.*		*Appearance of rubber or rubber composition after being heated in the incubator at 150° F. for 25 days, in each of the five series.*
	Oily and greasy matters.	*Copper* Cu0.	
1. White and Black Star Check.	0·260	absent	Good condition
2. Dark Brown Ring Check ...	0·384	present, but copper not estimated	Bad, and quite destroyed
3. Light ,, ,, ,, ..	0·499	ditto	Ditto
4. Dark ,, Check	0·128	trace	Damaged, but not quite hard
5. ,, ,, Broken Check ...	0·516	present	Hard and quite destroyed
6. Gold Check	0·548	absent	Good
7. Blue Pin Head Check	0·648	present	Hard and quite destroyed
8. Ruby Hair Line	0·301	absent	Good
9. Drab Fine Sheeting	0·264	,,	,,
10. Black and White Small Check Sheeting	0·206	,,	,,
11. Black and White Large Check Sheeting	0·445	,,	,,
12. Slate Sheeting...	0·181	,,	,,
13. Blue Check Sheeting	0·388	trace	Damaged, but not quite hard
14. Crimson Sheeting	0·471	not tested	Good
15. Black Fine Twill	1·500	0·332	Very much damaged, rubber quite hard
16. Black Broad	1·252	present	,, ,, ,,
17. Black Sheeting	1·552	0·150	,, ,, ,,
18. ,, ,, ...	2·805	present	,, ,, ,,
19. Black Plain Muslin	2·360	0·0157	Slightly damaged

The following pieces of cloth were analysed by one of us, because the rubber proofing had perished within a few weeks or months after being applied to them. Besides being analysed, a piece of each was taken, and one-third of it cut off and put aside. The oily and greasy matters were then removed from the other two-thirds by washing with ether: the part so washed was next divided into two equal parts, one put aside and the other boiled with 1% hydrochloric acid solution and washed till t cop was removed and dried. These three joined together, end to end, in a li , a another black cloth similarly

being left in its original condition, one having all the oily and greasy matters removed, and the third having both oily and greasy matters and copper removed; these were again joined in a line to a piece of grey cloth in its original condition, and to a piece of the same from which the oily and greasy matters were removed. It was, of course, unnecessary to use a third piece of this cloth, as it was free from any trace of copper. The eight pieces thus arranged in one line were divided along the line into two parts; one was covered with a continuous sheet of pure Para india-rubber, the other piece was covered with a rubber composition. Both were vulcanized by the cold process, and afterwards arranged in loops, and hung in an incubator at 140° Fah. for eight days. After that time the rubber on both pieces of grey cloth and the two pieces of black cloth, from which both grease and copper had been removed (in both series), was found to be perfectly sound, whilst the rubber on the two black cloths in their original condition, and on the two from which the oily and greasy matters had been removed, but in which the copper remained, were completely destroyed, the effect of the oil and grease in contact with the copper. (Some of the copper contained in cloth is usually found in solution in the oily or greasy matters also present). The effect is to reduce the rubber to the condition of a soft sticky substance, resembling grease in consistency, and to this condition the proofing is soon brought when the oily matter present in copper mordanted cloths exists in considerable quantity. The mixture thus produced is often absorbed into the fibre of the cloth, leaving it in a somewhat limp and sticky condition; when, however, the oily and greasy matters are removed, the rubber simply becomes hard. It is curious, therefore, to find that the presence of copper, even when oily and greasy matters are absent, is almost as destructive to the rubber, on rubber

proofed cloth, as when they are also present. The following table gives the proportions of oily and greasy matters present in the two samples of dyed cloth above-mentioned, and also the percentages of copper contained in them, and also the proportion of copper contained in two cloths, marked "E" and "C," which had been proofed, and become hard within a few weeks or months :—

	Per cent. Oily and Greasy Matter.	Copper Oxide. (CuO).
Black Cloth ("I")	3·38	0·29
*Decomposed Proofed Cloth, said to be same as above after proofing ("E")	——	0·12
Black Cloth ("M")	3·14	1·30
*Decomposed Proofed Cloth, said to be same as above after proofing ("C")	——	0·33

Within the last few years a bright blueish black has been produced by means of copper salt with logwood, or more commonly by dyeing, first with logwood, using iron salts as a mordant, and finishing the dyeing with the use of a copper salt as a mordant, and it will be found that if cloth so dyed be proofed, the rubber will rapidly perish. It is remarkable that cloths proofed with a mixture of india-rubber containing a large quantity of "india-rubber substitute" (vulcanized oil) are not so easily affected by copper salts as those proofed with pure india-rubber. A curious piece of evidence as to the action of copper on rubber came into the hands of one of us, after proofing the above-mentioned pieces which had been divided into 3 parts as above described and obtaining the results just given. A chemist placed in our hands two pieces of the same black

* These pieces were prepared by the same manufacturer, and said by the proofer to be from the same lots respectively as the unproofed cloths marked "I" and "M."

Action of Metallic Salts on Rubber.

Saturated solutions of a number of metallic salts were made and painted over part of each small sheet of rubber (equivalent to about 1½ inches square), allowed to dry, and put into the incubator as above described. Along with each series several untreated small sheets of the same rubber were exposed for comparison, because, after some weeks, the pure rubber will itself become oxidised and lose its elasticity. Some insoluble or difficultly soluble compounds were also employed. These were mixed into thin pastes with water and painted on to the rubber sheets. The following substances entirely destroyed the rubber :—

Copper Sulphate.
„ Chloride.
„ Nitrate.
„ Ferrocyanide.
„ Oxide.
„ Sulphide.
Arsenic Iodide.
Silver Nitrate.
Strontium Chlorate.
Vanadium Chloride.
Red Oxide of Manganese.
Black „ „
Bismuth Chloride.

The following substances *considerably damaged* the elasticity of the rubber but did not entirely destroy it :—

Ferrous Nitrate.
Sodium Nitrite.
Uranium Nitrate.
Ammonium Vanadate.

The following substances only *slightly damaged* the elasticity of the rubber :—

Lead Chromate.
Ferrous Sulphate.
Zinc Acetate.
„ Chloride.
Tin Peroxide.
„ Perchloride.
Chromic Acid.
Lead Borate.

The following substances were found to have no action whatever on india-rubber :—

Ammonium Sulphate.
„ Chloride.
„ Carbonate.
Potassium Chromate.
„ Bichromate.
„ Cyanide.
„ Acetate.
„ Carbonate.
„ Chlorate.
„ Iodide.
„ Nitrate.
„ Sulphate.
Sodium Sulphate.
„ Sulphite.
„ Chloride.
„ Carbonate.
Lithium Carbonate.
„ Chloride.
„ Salicylate.
Rubidium Chloride.
Barium Nitrate.
„ Chloride.
Magnesia.
Magnesium Sulphate.
„ Chloride.
Calcium Carbonate.
„ Chloride.
Strontium Chloride.
„ Acetate.
Aluminium Sulphate.
Aluminium Chlorate.
Zinc Chromate.
„ Nitrate.
„ Oxide.
„ Sulphate.
Ferric Chloride.
„ Acetate.
Manganese Chloride.
Cobalt Chloride.
Nickel Chloride.
„ Nitrate.
Thallium Chloride.
Mercury Bichloride.
„ Iodide.
Arsenious Acid.
Arsenic Acid.
Bismuth Nitrate.
„ Oxide.
Cadmium Bromide.
„ Chloride.
„ Iodide.
„ Nitrate.
„ Sulphate.
Lead Chloride.
„ Oxalate.
Tin Protochloride.
„ Protoxide.
Palladium Chloride.
Gold Chloride.

Effects of Minute quantities of Copper Salts on India-rubber.

We next directed our attention to the influence of minute quantities of the salts of copper on india-rubber. We took

small square sheets of the fine sheet rubber, adhering to paper, and painted one with a solution containing 10 per cent of sulphate of copper. On weighing the amount applied to the rubber it was found to be equivalent to 3·84 grains of crystallised sulphate of copper per square foot. This solution was then diluted with its own bulk of distilled water and a second sheet painted with the diluted solution. This second solution was again diluted with its own bulk of water, and a third sheet painted with it, and so on. There were thus prepared 6 pieces, containing the following quantities of copper salt per square foot of thin sheet rubber :—

	Grains of Sulphate of Copper ($CuSO_4 5H_2O$).	Equal to grains of Copper Oxide (CuO).
Sheet (*a*)	3·840	1·218
(*b*)	1·920	0·609
(*c*)	0·960	0·305
(*d*)	0·480	0·153
(*e*)	0·240	0·076
(*f*)	0·120	0·038
(*g*)	without copper.	

All these pieces were placed in the incubator at 140° Fah. for 9 days, when it was found that the sample (*f*) which contained the smallest quantity of copper, had entirely lost its elasticity and become quite rotten, whilst the piece (*g*), which contained no copper, was perfectly sound ; on examining the others they were all found to have entirely lost their elasticity, and to be hardened exactly in proportion to the quantity of copper salt placed upon their surfaces (*a*) being the hardest. It is, therefore, evident that an extremely small quantity of a copper salt has a highly injurious influence on rubber with which it comes into

intimate contact. In speaking on this subject to Mr. Thomas Rowley, of Manchester, he informed one of us that when he was an india-rubber manufacturer he had proofed large quantities of cloth with rubber, and had a book in which he kept samples of all he produced, many of which were now 15 years old. It struck us that it would be interesting to find whether any of the cloths which had been so proofed, and which had remained good for so long, contained copper, and Mr. Rowley very kindly placed his pattern books at our disposal. These patterns were arranged in numbers, describing the nature of the cloth and kind of proof, etc., and dates. We selected 7 samples, all of which, except one, had been steam vulcanized (*i.e.*), sulphur had been mixed with the rubber composition before proofing, and the combination between the two brought about by heating with steam afterwards. These patterns were perfectly sound, although about 16 years old.

We also selected one pattern of a brown cloth, in which the rubber proofing was decomposed and hardened, and which broke on the cloth being folded or bent. The following is the list of the samples taken:

Private Numbers.	*Date.*	*Description.*	*Results of Analysis.*	*Condition in January, 1881.*
No. 110	19 Nov., 1874	Black alpaca.	copper absent	good
,, 222	18 Jany., 1875	Black alpaca.	,,	,,
,, 252	22 ,, ,,	Black Paramatta.	,,	,,
,, 411	2 April, ,,	Blue black Paramatta.	,,	,,
,, —	7 May, ,,	Black fine sheeting (cold vulcanized).	,,	,,
,, 982	28 Aug., ,,	Brown fine sheeting.	,,	,,
,, 1150	24 Sept., ,,	Drab stout twill (black proofing).	,,	,,
,, 638	25 June, ,,	Brown cambric (black proofing).	trace	quite decomposed and hard.

All these samples were steam-vulcanized, except the

stretching, it seemed to be stronger and more elastic than the original rubber. With a view to finding the effect of a minute quantity of sulphuric acid on india-rubber, we soaked a piece of thin sheet rubber in solutions containing $\frac{1}{10}$th, 1, 2, and 5 per cent of sulphuric acid respectively, until the solution had thoroughly penetrated the sheet, which then appeared white. This was allowed to dry, and heated for some days to a temperature of 140° Fah., but the small quantity of acid exerted no injurious effect on the rubber. When, however, the rubber was taken from the strongest sulphuric acid solution containing 10 per cent of acid, dried and heated to 212° Fah. in a similar manner, it was soon destroyed. The sheets left in the cold for a month were likewise all sound except that placed in nitric acid, which was rendered quite friable, the elasticity having entirely gone.

Effects of Over Mastication on the life of India-rubber.

It has been so often asserted by india-rubber manufacturers that over mastication seriously damages india-rubber and leads to its rapid decay afterwards, that it seems extremely heterodox to say anything to the contrary. Still the results which we have obtained lead us to this opinion. In preparing rubber for spreading on cloth in the manufacture of water-proof fabrics, it is first passed between heavy rollers with a stream of water pouring over it, to remove stones or dirt which might be associated with it; it is then dried thoroughly and masticated between large heavy smooth rollers for a few minutes, these being gradually screwed closer and closer together during the operation. This softens the rubber, and enables it afterwards to be brought into a uniform solution when mixed with the naphtha, and the longer it is masticated the less naphtha is afterwards required to bring it to the proper uniform consistency for spreading. It is highly improbable that over-mastication would ever be done in practice, because the workman has

to collect the rubber under the rollers and pass it repeatedly through them till it attains the necessary degree of softness, so that as it becomes over-masticated it becomes soft and sticky, a point to which any experienced workman would not bring it. About four minutes is required for proper mastication, but one of us prepared some rubbers which were masticated for 15 and 21½ minutes respectively, and after spreading these on cloth we had a piece of the same cloth covered with properly masticated rubber (masticated during 4 minutes). All these were then placed in an incubator at 150° Fah. for a fortnight, but the sample of over-masticated rubber did not shew any sign of decay after that time, and to-day, six months after the experiment was made, the one appears quite as good as the other. The over-masticated rubber, had, when first produced, a slightly greater "tacky" feel than the properly masticated rubber, and this tackiness appeared not to have become greater or less after the lapse of six months.

Peroxide of Hydrogen.

The curious effect, or rather absence of effect, which chromic acid had upon india-rubber led us to make an experiment to find whether peroxide of hydrogen would oxidise and destroy it. We placed sheets of rubber both in alkaline and in acid solutions of that reagent for one month, and found that after that time the elasticity and strength of the sheets so treated remained unimpaired, a result which appears quite as surprising as the chromic acid result. Some years ago one of us found that ozone exercised a most injurious influence on india-rubber, especially when it was left in a stretched condition, and it might naturally be expected that peroxide of hydrogen would have exercised an equally injurious influence on it.

Notes on the Geological section exposed in the Railway Cutting from Levenshulme to Fallowfield. By Wm. Brockbank, F.G.S., F.L.S., and C. E. de Rance, Assoc. Inst. C.E., F.G.S., F.R.G.S., F.R.M.S., of H.M. Geological Survey.*

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PART I.

The Upper Coal Measures.

The Levenshulme section exhibits the "upper measures of the Lancashire Coal Field"—a description first used by Elias Hall, in the key to his Geological Map of Lancashire and Cheshire, where he adopts the term "Manchester Coal Field" for these Upper Coal Measures. Mr. Binney again used it in his paper on the Lancashire and Cheshire Coal Fields, read in 1839 (*Trans. Manchr. Geol. Socy.* Vol. I., p. 69). He there states that the limestones of Ardwick and Whiston are the highest portion known, and therefore may be considered the upper boundary of the field. These were considered to be of fresh-water origin. He also clearly pointed out in his sketch of the Geology of Manchester, that the "Lower New Red Sandstone" (Permian) is unconformable to the coal measures beneath.

The Collyhurst section was that which Mr. Binney had before him, and it long remained the only illustration of the junction of Upper Coal Measures with the Permians, and was visited by many geological enquirers accordingly. It was, however, a very unsatisfactory illustration, as the actual contact was never well shewn, and the passage beds were much covered up by drift clays. When the British Association visited Manchester in 1861 an excavation was made at the junction of the Permian sandstone with the Coal

* Communicated with the permission of the Director General.

Measures at Collyhurst, and a report upon this by Mr. Binney was published in the British Association reports, 1862. This excavation was visited by many of the leading geologists of that day, as it opened out a section not otherwise to be seen in England, and helped to clear up a very interesting problem in geology, which was afterwards fully solved by Sir Roderick Murchison. Previously to the excavation of this deep cutting, made, purposely, at Tinker's Brow, Collyhurst, the absolute point of contact had not been seen. The Permian strata were found to be dipping at an angle of 18°, and the Coal Measures at an angle of 24°.

What was thus indistinctly seen at Collyhurst in 1861, has been most fully displayed in the railway cutting at Levenshulme, and has afforded an opportunity which may never occur again of seeing a complete section of Coal Measures underlying the Permians. The latter consists at Levenshulme of the "Lower Red Sandstone," of Tinker's Brow, Collyhurst, as it was called in Mr. Binney's time. The beds in contact with it belong to a somewhat higher portion of the Upper Coal Measures, and are, therefore, of great interest, being possibly the highest Coal Measures known in England. Leaving the description of the junction with the Collyhurst Sandstone of the Permians for our next paper, we will proceed at once with the purple beds which underlie them, and which, though undoubtedly of Upper Coal Measures age, are to some extent of a transitional character.

The purple beds which immediately underlie the Permian Strata near Slade Lane, and which are the uppermost of the Upper Coal Measures, remind one of us of the *breccia* or *brecktam*, which always forms the lowest member of the Permians in the North of England. Here, however, the Permians commence otherwise, but the uppermost member of the Carboniferous strata has the brecciated character strongly marked. It has a deep purple colour,

and is very hard when freshly quarried, but breaks up into angular fragments, very readily, when exposed to weather, and afterwards becomes harder and harder under exposure to the atmosphere. It appears to have been formed by the destruction of the adjacent Upper Coal Measures, which consisted of alternating marls, hematite iron, clays, and limestones. These, all triturated and mixed together, would form a very strong natural cement, and this would exactly describe these purple beds. It is, possibly, open to question, in the opinion of one of us, whether these "brecciated marls" may not really belong to the Permians, if they are not a transition zone, representing the "brockram," "breccia," or "crab rock" of the North of England and South of Scotland.

The first limestones are tilted a little by slight step faults which occur at Slade Lane, the strata there being also bent over in a curve to the southwards, but the general parallelism of the beds is very marked, and the whole section, when viewed from end to end, shows a very parallel set of strata, without a break, and with only very slight faults to disturb its perfect regularity. These brecciated marls abound in nodules, termed by Warwickshire workmen "fish-eyes," [See H. T. Marten, M.I.C.E., F.G.S., in Underground Water Report, drawn up by C. E. de Rance.—*British Association Report*, 1882] from their likeness to the eye of a fish, but for no other reason. They form round green spots in the purple beds, and with dark centres; varying in diameter from ½-inch up to 1½-inches. These "fish-eyes" are everywhere present in the strata of the whole section, and are believed to be coprolites, as the central nucleus has been tested by Mr. Fowler, of Owens College, and found to yield carbon and phosphoric acid. The microscopic examination of these spots reveals their coprolitic character.

The bedding is extremely irregular, and is marked by green partings of sandy marl. The mass is also broken up

by joints and cross-fractures into roughly cubical blocks, and these joints are also filled with green sand. The inclination of the beds is about 36° west, 20° south, and the bedding assumed a very strong curve southwards across the railway excavation, probably on account of the fault which is seen near Slade Lane and which has tilted the limestones at that point. There are many pockets of green sands in these beds. These and the green partings frequently contain geodes of crystals of calcareous spar. A diligent search was made for fossils, both in the beds, and from the material loaded into trucks as the excavations proceeded, but none were found. It is probable that the conditions under which these brecciated beds were formed were unfavourable to shell life, and that no fossils except the coprolites are likely to be found in them. These, however, furnish abundant evidence of animal life, possibly amphibian. These coprolites were very abundant throughout the marl. The brecciated marls are altogether 72 feet in vertical thickness, and they rest upon the uppermost limestones, which are reached under Slade Lane bridge. These limestones are very flaglike, being quite evenly bedded, and varying in thickness from 1 in. to 6 in. The slab faces are always covered with greenish laminated shale, which splits off in thin wafers on exposure to the atmosphere, and yields beautiful bright red fish scales and many small spines, always stained with hematite. The jointings in the limestone are frequently marked by beautiful dendritic and "fernlike" crystals, probably manganese, which always commence at the natural edge (jointing) of the slab. The cracks in the limestones are frequently filled with orange-coloured calc-spar, probably stained by hematite. It also sometimes occurs in cavities, and in bright orange spots in limestone. The same colouring matter has also probably given the grey limestone its pinkish tinge of colour. The fractures of this group of limestones—or marbles they might be

called—are conchoidal, and frequently the broken surfaces have a waved appearance, like rounded creases. The grain is beautifully regular, and it takes a high polish. It is in fact a marble of a beautiful pinkish grey colour. It is mottled all over with greenish circular spots, some with dark centres. These spots pervade every bed, but there are fewer in the upper, whilst the lower marbles are so thickly mottled as to be almost made up of mottlings. These green spots appear to be indications of the presence of organic remains. Some are certainly coprolitic, and others are produced by *Entomostraca*, *Annelida*, or other minute organisms, whose shells make up the mass of the limestone. One of the thicker beds of this first group contains large numbers of grey nodules, which are clearly coprolitic, and which, under the microscope, are seen to contain reddish specks, hematite-stained, as in the case of the fish remains which abound in the same rocks. In one remarkable instance a small tooth is to be seen in the coprolite. The small annelid *Spirorbis Carbonarius*—formerly known as *Microconchus Carbonaria*—is present in all these limestones, but more sparingly in the upper beds. It becomes more and more abundant in the lower beds, until in some instances the rock appears to be absolutely made up of its remains.

This first group of limestones has a very different appearance in every way, except colour, from those that follow. It was evidently formed in very quiet waters, where small fishes fed on the tiny annelids and crustaceans, and where the currents were gentle and recurrent. The beds are perfectly regular, and the limestones contain the remains of the small fish, always in fragments—single scales, and odd detached spines; as if they had been entombed in this fragmentary state. The green shales which coat the limestone are similar, and contain the same fragmentary remains of fish—hematite-stained, and always beautifully preserved. *Leaia Leidyi* var. *Williamsonia* was found in these

thin shales. Annelids like the *Spirorbis*, which here abounds, are to be found on our sea coasts, feeding on seaweed, and the *Entomostraca* are likewise existing now in sea water and stagnant pools, where they furnish food for small fish such as are found in these limestones. When polished this first group of limestones takes a beautifully even surface of a pinkish grey, upon which a few *Spirorbis* may readily be seen with the naked eye, but no distinct trace of other fossils. No fossils were found on breaking up a large quantity of the stone. When, however, a thin section is prepared for the microscope it is at once seen that the solid rock abounds in organic remains; and it is clear that the tiny crustaceans which built up the mass with their thin shells are not to be seen by the naked eye. *Entomostraca* abound in these limestones as well as the *Spirorbis*; and there are many spines visible which may be the antennæ of some shrimp-like crustaceans.

The beds of limestone vary in number at different points; the thin flag-like members part and re-unite in the course of a few yards. The sections on the north and south sides of the railway cutting were as follow:—

Summary of Group No. 1.

North.	ft.	in.	South.	ft.	in.
Limestone ...	0	2¾	Limestone ...	0	6 to 8in.
„ ...	0	4¾			
Green Shale..	0	1	Green Shale..	0	¾
Limestone ...	0	2	Limestone ...	0	2½
Shale	0	¼	Shale	0	¼
Limestone ...	0	3	Limestone ... (*Spirorbis*)	0	4
Green Shale..	0	1	Shale	0	½
Limestone ...	0	4	Limestone ...	0	7
„ ...	0	4	Green Shale..	0	2
Green Shale..	0	2			
Red Rubbly Rock			Red Rubbly Rock ..	0	9

The thin seam of green marl, which underlies the lowest of this group of limestones, is very fossiliferous with minute organisms. *Spirorbis* shells abound in it, and there are to be seen under the microscope minute and very delicate bivalve shells, detached and often much broken up. The marl is frequently cellular, but the white partings are probably merely calcareous fillings of the spaces round the sandy grains. There are, however, small sponges and *Entomostraca;* in fact, the minute fossils here present are similar to those seen under the microscope in sections of the limestones which overlie them. A large quantity of this interesting green marl has been saved for future examination, as it appears likely to yield the organisms which are found in the substance of the limestones.

Under the green marls come 9 inches of red rubbly rock, deeply stained by hematite, and containing about 10 per cent of iron.

The next measures consist of variegated marls, purple and green, from 5 to 7 feet thick, which are full of plant remains. Coprolitic nodules (fish-eyes) are also abundant. The plant stems vary from ¼in. to an inch in diameter, and are always flattened. A large number have been examined, but they are always filled in with a fine micaceous marl, and no trace of structure can be made out, except the outward bark and the form of the stems. Leaf-like markings occur in plenty, but no distinct leaf forms have been detected. Nut-like objects occur, with the stems and leaves, in abundance, but always filled in with a micaceous matter, without any trace of shell. It has been suggested that these plant-remains represent seaweeds, or water plants, and that the nut-like ovals have been the air vessels. The general appearances are those of seaweeds. A large quantity of this clay with plant-remains has been reserved for future examination.

Following this plant bed comes a long series of variegated shales, purple at first, and becoming redder towards the base. These are again followed by variegated bright purple and green marls, and again a mass of purple shales with dark bands, becoming red towards the base, where bright hematite red clays terminate the series. The total thickness of marls and clays between the 1st and 2nd groups of limestones is thus 28′ 9″, or say about 30 feet.

The occurrence of hematite iron in the Upper Coal Measures is generally well marked over England, and it is exemplified in this section. At several points the beds are very strongly marked by hematites. It was pointed out by the late Sir R. I. Murchison that the hematite ores of Furness had been produced at the close of the Carboniferous epoch, and the deposits which had then been made in the fissured rocks of the coal measures and limestones had been sealed in by the breccias of the Permians. It is the same here in a lesser degree. We find all the strata tinged with hematite, and several of the clays, which have been analysed by Mr. Bone, of Owens College, yielded as much as 10% of iron. All the fossils are coated red with hematite, and bits of pure ore are found in many positions. The section, therefore, furnishes this fresh evidence of the prevalence of hematite in the closing period of the carboniferous epoch.

The hematite band at this point was a very striking feature in the section, and strongly impressed us with the possibility of its marking the impending change of conditions here which obtained in the North of England just before the Permian conglomerates were formed.

2nd Group of Limestones.

The second group of limestones commences 90 feet east of Slade Lane Bridge, and is a great contrast to the first

group. It commences with a very rough limestone, 4 inches thick. When polished it has a pinkish brown colour, mottled over with bright spots, which prove to be *Spirorbis* shells cut through in every direction. The number of individuals, roughly counted, amount to 300 to the square inch, which would give about 5,000 to the cubic inch. The limestone is, in fact, almost made up of this tiny annelid. The second limestone of this group is 10½ to 14 inches thick, with a very irregular surface, the hollows filled in with green shale. It has a deep purple fracture, and shews nearly as great an abundance of *Spirorbis* when polished. In addition, it is mottled with oval and circular greenish spots; under the microscope these are shewn to be produced by *Entomostraca*—beautiful oval shell sections are everywhere present. The third limestone of No. 2 group is 8½ inches thick, and has the same appearance; when polished it has a beautiful dark marble lustre, much mottled with dark and light oval patches. The dark mottlings have a granulated substance, and are probably coprolitic. It is also dotted over with an immense number of *Spirorbis* shells. A microscopic cutting taken from another block shews the marble to be completely made up of small organisms and beautiful oval shells of *Ostracoda*, cut through at varying angles, some showing the overlapping of the bi-valve shells. The delicate shells are so completely absorbed into the substance of the limestone that it is impossible to detect their presence except by the green mottling which they produce, and which is very noticeable. There are also present many minute filiform objects, probably *Serpulites* and other annelids—many tiny bones are also visible. The 4th limestone of No. 2 group is 1 foot 1 inch thick, and a thin parting of brown shale separates it from the 5th limestone, which is 1 foot 5 inches thick. They are frequently conjoined, forming huge blocks, so they may be here taken together. They have the same

purple fracture, mottled all over with green oval spots, and are thickly spotted with *Spirorbis*. They take a good marble polish—and would be of great value for decorative purposes if they could be quarried in large blocks. Unfortunately this is not the case—they have extremely irregular surfaces, and altogether a roughly brecciated appearance. Under the microscope they again reveal the presence of *Entomostraca* in great abundance, which Prof. Rupert Jones considers to be of the *Carbonia* group of the *Ostracoda*. There are also many curved spine-like objects, which may be annelida of the *Ditrupa* class. It will be seen, therefore, that all the members of the second group bear a strong family resemblance, and that they differ altogether from the first group in their construction, although the fossils are similar.

Summary of No. 2 Group.

	ft.	in.
Purple and green marls	0	3
1st Limestone rough	0	4
Purple calcareous marls with green joints	0	8
2nd Limestone purple fracture	0	10½ to 14
Very irregular surface, the hollows filled in with the green shale above it.		
Yellow parting	0	¼
3rd Limestone, purple fracture	0	8½
Brown marl with Limonite	0	3
Green marl shale	0	3
4th Limestone, often joined in one huge block, but always showing the parting	1	1
Brown parting	0	1
5th Limestone	1	5

The next measures are very irregular, and have not been so carefully examined. They are as follow :—

	ft.	in.
Yellow marl	0	3
Purple shaley marl	0	1
Limestone nodular and irregular deep purple fracture	0	10
Sandy purple marl, in the base of it Limestone nodules, resting on the green marl	0	10
Green marl, with *Spirorbis* shells, pebbles at the base of it	0	6
Soft purple marls	0	10
Hard purple and variegated marls, with plant stems and fish-eyes, probably coprolites	4	0
(In this bed the plant remains were numerous, the pipe-like stems passing through the beds, but no definite structure, and no clearly defined leaves, were found. They were not very carefully examined.)		
Purple shales, with green partings	5	3

3rd Group of Limestones.

The thick marls and shales are followed by the 3rd group of limestones. The 1st limestone is 5in. thick, and after a thin marl parting a 2nd limestone appears, 5 to 7 inches thick. This has a deep purple fracture—another ¼ inch parting brings us to the 3rd limestone, 7in. thick. These three limestones are similar in their characteristics. When polished they have a beautiful marble surface of pinkish grey colour, of the shade now called "Esterhazy," spotted all over with *Spirorbis* in great profusion, and also mottled with yellow-green circular markings, varying from ½in. to tiny round dots. All these indicate the presence of organic remains, of which there must be thousands in a cubic inch. A thin cutting, under the microscope, reveals large numbers of delicate shells of *Entomostraca*, and others with more substance and of more oblate curves. They are in perfect condition, the overlapping in the bivalves being

clearly shewn. Many other small organisms are crowded into the field of view.

These three limestones are succeeded by a 7in. band of yellow marl, and again by 11 inches of purple marl, after which we have a (4th) bastard limestone, 6in. thick, which has not been carefully examined. This is followed by purple marl, abounding with "fish-eyes," and then a (5th) bastard limestone, 8in. thick. A mass of variegated marls, 4ft. thick, follows, much mixed with hematite, the lowest bed being of a deep red.

Summary of No. 3 Group.

	ft.	in.
(1) Limestone	0	5
marl parting	0	0¼
(2) Purple limestone	0	5 to 0 7
marl parting	0	0¼
(3) Limestone	0	7
Yellow marl...	0	7
Purple marl...	0	11
(4) Bastard limestone	0	6
Deep purple fracture	0	0
Purple marl with "fish-eyes" ...	0	2
(5) Bastard limestone	0	8
Marls with hematite	4	0

The 4th Group of Limestones.

Immediately under the red marls, the 4th group commences with

	ft.	in.
(1) Limestone	1	2 to 1 4
Green and purple shale	0	1¼
(2) Limestone (purple fracture)	0	4½
Purple marl...	0	3
(3) Limestone	0	9

which form a small compact group, being separated from the next by a mass of marls and shales. These limestones are very rough in surface, as they are also in substance, and they will not take a good marble polish, being much pitted

with small holes. The colour also is peculiar, being a dark liver-coloured purple—with yellow stain lines, and deeper purple blotches. Veins of calcite run across the blocks, and *Spongia* is not visible if at all present. The limestones have a brecciated appearance, the fragments cemented by calc-spar. This group of limestones appears to have been formed in troubled waters, and under very disturbed conditions. The presence of the hematite iron resting upon them is of interest, as shewing the transition period at which these beds were deposited and formed just before the Permians. A thin section of this limestone looks like a smear of hematite on the glass slide, and when viewed under the microscope it is seen to be made up of small angular fragments, everywhere iron-stained. Many comminuted shells are present, but no perfect shells, or *Entomostraca*, although abundant fragments of both. It is interesting thus to observe in the microscope the characteristic evidences seen in the outward appearance of the rock and its surroundings. These limestones rest upon a series of shales and marls, 17 ft. thick, commencing with a violet purple, and passing in distinct beds of varying colours, gradually, to a deep rosy red. The beautiful gradations of colour in these beds interested us much, so that we used to call them the "Æsthetic" marls. In the section, Plate V., as nearly as possible, the exact colours taken from actual samples of the marls are reproduced. These marls were evidently formed by the grinding down of the limestones and red clays, and were re-deposited under very quiet conditions, in still waters. The beds were perfectly regular, the colours varying like the leaves of a book, green grey, brown, and pink alternating in beautiful sequences, the mass gradually deepening in redness towards the base, as is usual in this section. The red hematite clay at the base of these marls was found by Mr. Bone to contain 10·55 per cent of iron, and was highly calcareous.

5th Group of Limestones.

The 5th group of limestones succeeds these red marls, and commences with a bed of limestone, 3 ft. 6 in. thick, but with half-inch partings at 6 inches from the base, and at 1 ft. 10 in. from the base. There was an inch of brown limonite on the surface between the limestone and the hematitic red marl. The limestone had a green shale coating, and all the crevices were filled with it. A fine fish-eye nodule (coprolite) was found in one of these shale partings.

The upper member of this group is a very pink limestone, which polishes badly, being pitted with small holes. It has an extremely irregular surface, and a thin section shows the same irregularity in the substance of the stone; wavy lines pass through the mass as in an agate. It is almost entirely made up of *Spirorbis* and other small shells, and there are many tiny bones. A section under the microscope shews clearly the irregular constitution of this limestone. It is all curved lines of deposition, crowded with organic remains. *Entomostraca* are present in great numbers. It also contains the fish-eye circles, with dark centres. In one of these the central spot was granulated, and contained a pink spot. Red patches are always found with organic remains in these limestones, hematite having been absorbed by the tissues. The *Entomostraca* in this section are entire, and the cavities filled with crystals of calc spar, which form beautiful objects with the polariscope. They have been identified as of the *Carbonia* group. The ¼ in. power shows curiously jointed tubular organisms, probably *Ortona Carbonaria*, a tubicular annelid. Another series of variegated marls succeeds this group, about 16 ft. thick—purples, greens intermixed, followed by a bright red hematite band, which is again followed by brown, purple and green marls. These bands are full of the fish-eye nodules, which are noticeable all along the face of the cutting, and they

are fossiliferous, as a vertebra about 1in. diameter, probably amphibian, was picked up by a visitor near one of the beds from the material scattered in loading the railway trucks. The exact spot where it occurred could not be ascertained, and although diligent search was made on several occasions nothing else of the kind was found. It is, however, a very fossiliferous horizon, as is shewn by the prevalence of the fish-eye nodules of large size representing animal life of some sort—fishes, turtles, or amphibians. The next band of limestones also is the most fossiliferous of any, and it immediately underlies these marls.

6th Group of Limestones.

		ft.	in.
	Green marl, on the Limestone	0	1
(1)	Limestone. The last ½in. separate forming the bone bed	0	11
	Green parting	0	0½
(2)	Limestone, nodular and very fossiliferous	0	4
	Green calcareous shale	0	5
	Purple marls...	0	11
(3)	Limestone—hematite blotched	0	3½
	Marl	0	0¼
(4)	Limestone—very rough faced. Fish and bone bed	½ to 1	¼
	Yellow marl	0	1
	Purple marl	0	2
(5)	Limestone, fossiliferous...	0	0¾
	Reddish marls	0	10

This No. 6 Group contains by far the most interesting fossiliferous limestones. We gave them the name of the "blue limestones," but they were somewhat piebald, portions of the same block being pinkish grey in one part, and dark blue grey in the other. The pinkish part was crowded with *Spirorbis*, and the blue frequently one mass of shells. Some of these have been examined by Mr. E. T. Newton, F.G.S., of the Geological Survey, who recognized amongst them the *Anthracomya* (*modiola*) figured by Sir R. Murchison in

his "Silurian System," p. 84, as having been found at Ardwick, Manchester. *Posidonomya* and several other shells have been found, but the names have not yet been settled. Fragments of bone were seen in almost every block, as well as on the surface, under the green marly coating, but fast to the blue limestone. The fish remains are in the hands of Mr. J. W. Davis, F.G.S., F.L.S., of Halifax, for identification. They include ribs, teeth, spines, and scales, and will probably be found to belong to the *Megalichthys* and *Strepsodus*. Unfortunately all these fish remains occur in detached fragments, owing to the thinness and irregular composition of the blue limestone in which they generally occur, the rock itself being frequently not over an inch in thickness. Sometimes it varies in the same slab from 1 inch to 4 inches in a foot length, and with a most uneven, undulating surface. Thin sections of this No. 6 group of limestones shew an amazing variety of organic remains. Firstly, they are crowded with fragments of the shells of molluscs, intermingled with the more delicate shells of crustaceans, and with spines, bones, and other fragments of fishes in profusion. The small organisms which fill up the field of view are of a blue grey colour, and amongst them, cris-cross, are bones of a reddish brown colour. The ¼in. power gives the cellular substance of these small bones perfectly. They belong to tiny fish, which probably fed upon the *Entomostraca*, and whose presence attracted the larger fishes, which in turn preyed upon them.

The identification of some basis, from which the true position of the Ardwick limestone beds can be ascertained, with reference to the Levenshulme series, has had our careful attention. We have come to the conclusion that the Ardwick bed, which contained the remains of the *Megalichthys Hibbertii*, is the same as this No. 6 Group. It is a very marked and peculiar bed, consisting of two colours, the pink containing *Spirorbis*, and the blue containing shells of the *Anthracomya*. The fossils of the Ardwick limestone

were first described by Prof. Phillips in 1836. He was the first to recognise the *Spirorbis*, and he recorded the discovery of the *Megalichthys Hibbertii* in these beds. A fine set of Ardwick limestones with scales of this large fish is in Peel Park Museum, and a large slab of the same is now before us; it is of this piebald stone; the pink portion is full of *Spirorbis* and dotted over with large scales of *Megalichthys*, whilst the other portion is of the blue limestone, covered with shells, amongst which are the *Anthracomya* above referred to. We have had thin sections cut from the two varieties in this Ardwick limestone, and under the microscope they are almost identical with our No. 6 Group, the same shells, bones, *Entomostraca*, colours, and the general agreement being undeniable. Here, then, we appear to have a datum, all the groups from Nos. 1 to 5 inclusive being above the Ardwick limestones of Prof. Phillips, Mr. Binney, and Prof. Williamson, and Nos. 6, 7, and 8 being the old Ardwick beds, as they reappear slightly different in thickness, etc., at Levenshulme.

The piebald colours in this group are very peculiar, and not easily to be accounted for, neither is it easy to account for the extreme irregularity of the beds. The only separation between No. 6 and No. 7 Group is a band of reddish marl, 10in. thick.

7th Group of Limestones.

		ft.	in.	
(1)	Limestone	0	8½	
	Bright green marl	0	2	
	Compact hematite red marl	0	1	
	Earthy ironstone—olive brown ...	0	2½	
	Purple marl	0	3	
	Calcareous nodules in yellow marl ...	0	6	
	Purple marl	1	0	
(2)	Limestone, very rough, lumpy with purple fracture	1	3	to 1·6
	Green marl	0	2	
	Purple marl	0	4	
	Green and red marls	1	0	
	Dark purple and grey marls	2	0	
(3)	Limestone fish bed	0	1	
	Green marl	0	4	

These (No. 7) limestones have all dark purple fractures, with irregular wavy surfaces, 2 in. deep in the undulations, which are filled in with green shale and limonite. When polished, the surfaces are beautifully bright and veined like a fine "Sienna marble" of a reddish-purple tint, the veinings being yellow and red. *Spirorbis* spots are dotted all over, and there are curious angular patches of a deeper colour. A thin microscopic slide furnishes a very beautiful subject, being crowded with perfect *Entomostraca*, the shells in pairs, and many tubular organisms of the annelida amongst which is the annulated tube of the *Ortona Carbonaria*. The ¼ in. power shows the jointings and the central tube. A shell of *Planorbis*-like form is present in this as in several other slides, which is probably the larger form of *Spirorbis—S. Ambiguus*. The lower 9 in. bed has the *Entomostraca*, but not the other items.

8th Group of Limestones.

Limestone	...	...	...	2	0
ditto	...	...	...	1	10
Green marls	...	...	...	1	0
Red marls. Proved		...	...	4	0

The red marls were not clearly seen on the north side, as the deep cutting stopped abruptly at the last limestone, but the red clays were seen for some 50 yards further eastward at the base of the boulder clay. The No. 8 Limestones are the most massive of all, the two making 3 ft. 10 in. thickness, and frequently conjoined. The eastern face of the blocks was much striated by glacial action, the termination of the limestone edge having evidently felt the force of the glacial drift; large detached masses of the limestone were found in the clay for many hundred yards eastwards. The blocks shewn in our section (Plate V.) are from actual measurements, as also the drag of the coloured marls from the same cause.

These last limestones (No. 8) are, from a marble mason's point of view, the most valuable of all, being, when polished, the most beautiful of the series. They have a lovely deep colour, mottled with paler pink spots, and the marble polish is perfect. The *Spirorbis* with which we started is here in abundance. A thin section under the microscope shows the red markings to be hematite stains, mottled further with hosts of *Spirorbis*. There are many shells of *Entomostraca* and fragments of shells, and long curved tubular objects, probably *Serpulites Carbonarius*. The veining is most noticeable under the microscope; it runs across the subject like rivers filled in with clear crystals of calc spar, as if the whole limestone were brecciated, the intervening spaces having been filled in by subsequent crystallization.

N S.

B O
SAND
A PURPLE SHALES WITH DARK BANDS.
HEMATITE RED TOWARDS BASE.
Ft. thick.
Purple and Green
Bastard Rough Lim
Purple Calcareous
Limestone (deep pu
very irregular su
lows filled with
Yellow Parting.....
Limestone (purple)
Brown Marl or Lim
Green Marl Shale

ft	in	
[illegible]	0	1
[illegible]	0	11
[illegible]	0	[illegible]
[illegible]	0	4
[illegible]	0	5
[illegible]	1	11
[illegible]	0	[illegible]
[illegible]	0	[illegible]
[illegible]	0	[illegible]
[illegible]	0	1
[illegible]	0	2
[illegible]	0	[illegible]
[illegible]	0	10

Limestone
Bright Green M
Compact Hematit
Earthy Limestone
Purple Marl
Calcareous Nodu
Purple Marl
Limestone, very
Green Marl
Purple Marl
Green and Red M
Purple Gray Ma

On New Forms of Stereometers. By W. W. Haldane Gee, B.Sc., F.C.S., and Arthur Harden, M.Sc., Ph.D.

(*Received March 13th, 1891.*)

The problem of experimentally determining the volume of a body to which the usual hydrostatic methods are inapplicable was first attacked in 1797 by Capt. H. Say (*Annales de Chimie*, XXIII, 1), who described an instrument (Fig. 1) devised for the purpose of determining the specific gravity of gunpowder.

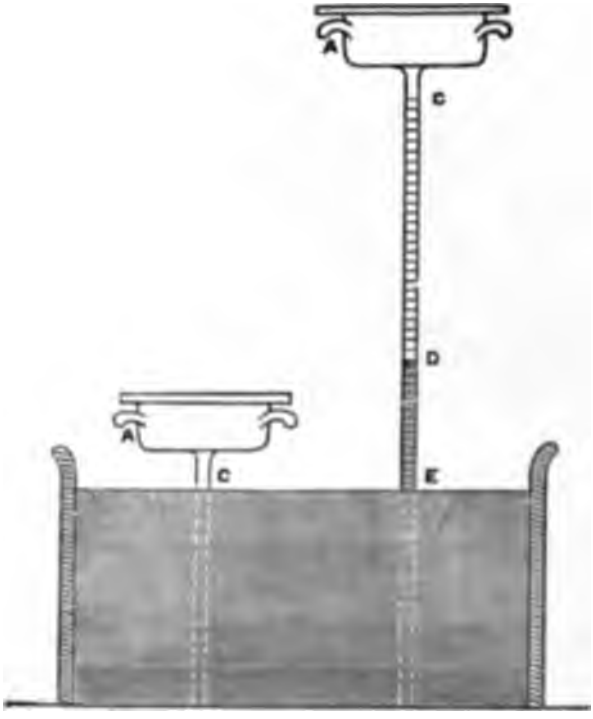

Fig. 1.

The vessel A, the stem of which is graduated and calibrated, so that both the distance, and also the internal volume of the tube is known between any two graduations, is immersed in mercury up to a fixed mark (C) on the stem. A ground-glass plate is then applied so as to close the vessel air-tight. The apparatus is now raised to a convenient extent, and the level of the mercury inside at D, and outside at E of the stem noted.

The body of unknown volume is then placed in A and the experiment repeated.

I. To find the volume V of the air in the vessel A.

Let the atmospheric pressure ... ... $= m$
The pressure after lifting, *i.e.*, $m - DE$ ... ... $= n$
The increase of volume CD due to diminution of pressure ... ... $= v$

Then

$$V + v = \frac{Vm}{n}$$

and

$$V = \frac{nv}{m - n}$$

II. Let $x =$ the volume of the substance,

Then in the second experiment $V - x$ must be written for V, its value calculated and the value of x found by subtraction.

A very similar apparatus (Fig. 2) was described by Leslie in 1826 (*Quarterly Journal of Science and Arts*, XXI, 374), and was used by him to ascertain the specific gravity of various powders, such as charcoal, flour, volcanic ashes, etc.

To obviate the error arising from absorption of air he determined the volume with different degrees of dilatation.

W. H. Miller (*Phil. Mag.*, 1834, V, 203), in 1834, introduced a considerable improvement in the construction of Say's instrument, which will readily be understood from the

Fig. 2.

accompanying diagram (Fig. 3). Greater accuracy in reading off the height of the mercury, and freedom from the error due to capillary depression, are attained by the use of two parallel tubes. The apparatus was specially designed for determining the volume of a standard weight, which could not be treated in the usual way. (Cf. *Phil. Tran.*, 1856, 800).

In 1840, H. Kopp (*Ann. Chem. Pharm*, XXXV, 17), constructed a volumenometer (Fig. 4) in which the pressure of the air is increased, instead of being decreased, as in the previous instruments. The ground-glass plate (M) closing the vessel (R), is held in position by a screw L and cork Q, and the volume of air is then diminished by moving the

piston in the cylindrical tube (T) until the mercury in C has reached a fixed position marked by needle points in the

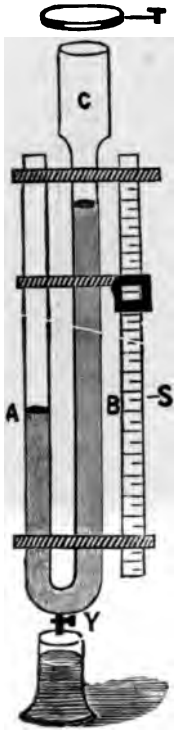

Fig. 3.

vessel C (*a*,*b*,*c*,*d*.). The pressure required to effect this diminution is read off on the gauge S S. The constants of the instrument were determined by placing distilled water in R, and no allowance was made for the deviation from Boyle's law shown by air saturated with moisture. The results thus obtained with substances such as tin and lead were exceedingly accurate. It was observed that substances which absorb air, such as charcoal, cannot be employed with this instrument.

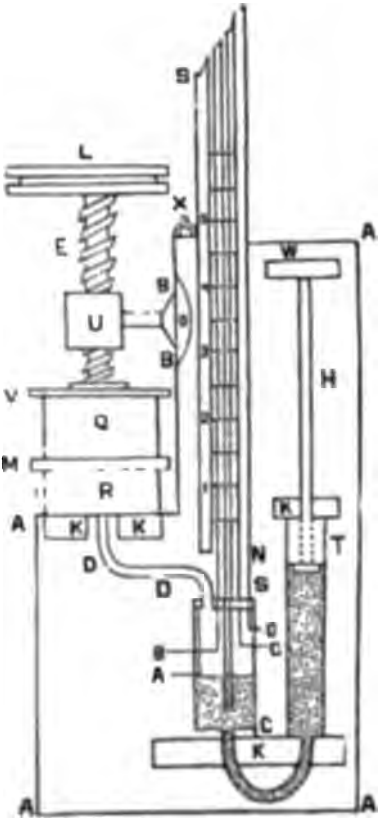

Fig. 4.

Another form of stereometer (Fig. 5) somewhat resembling that of Miller, was described in 1845 by Regnault (*Annales de Chimie et de Physique* (3), XIV, 207).

In this instrument either decrease or increase of pressure can be employed, and the apparatus is so arranged that it can be filled with dry air. Notice is also made here of the fact that some porous substances absorb air. This is detected by the fact that they give different results according as the pressure is increased or diminished.

A number of determinations has been made by means of this instrument, or an allied form by Grassi, *Annales de Pharmacie et de Chimie* (3), XI, 184.

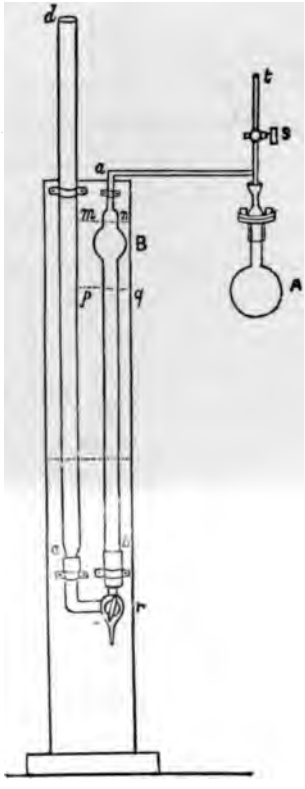

Fig. 5.

Buignet, Ibid (3), XL, 164.

Fillol, *Annales de Chimie et de Physique* (3), XXI, 417.

Other forms of the stereometer have been designed by:—

Baumhauer, *Archives Néerland*, III, 385 (1868).

Rüdorf, *Wiedemann's Annalen*, VI (1879) 288.

Tschaplowitz, *Zeit. für Analytische Chemie*, 1879, XVIII, 440.

Paalzow, *Wiedemann's Annalen*, XIII (1881) 332.

Raikow, *Chem. Zeit.*, 1888, 525.

A curious instrument of this character was also invented by Harting (*Archives Néerland*, 1872, VII, p. 289), to determine the volume of the air chambers of living fish.

Notwithstanding the numerous forms of volumenometer which have been described it is curious that none of them has come into general use for density determinations.

With the object of designing a simple and fairly accurate form of volumenometer, we commenced a series of experiments in the physical laboratory of the Owens College in 1883. It was first of all found that there were so many practical difficulties to be overcome in constructing Kopp's volumenometer that any idea of employing it as a laboratory instrument had to be given up. The chief difficulty was the construction of a glass cylinder and piston tight to mercury under the pressure of one or two atmospheres. This form of the apparatus was therefore abandoned, and an instrument (which is figured in Stewart and Gee's *Practical Physics*, Vol. I.) constructed on the type of Miller's stereometer. The pressure was altered, as in the instruments of Regnault and Miller, by running mercury in and out of the apparatus. This process is very objectionable in an apparatus intended for general use, and, moreover, is liable to error on account of the difficulty of getting rid of air bubbles in the narrow parallel tubes.

At this point our experiments were interrupted, and were not resumed until the long vacation of 1889. An instrument was then arranged as shewn in Fig. 6.

A glass tube, about 15 mm. in diameter, was constricted at four points, at each of which a cross was etched with hydrofluoric acid. This tube (A) was firmly clamped on to a vertical wooden stand, and was connected by thick india-rubber tubing (B) with a piece of straight tubing (C), which could be moved up and down in a groove, a millimeter scale

being placed between t ı › tubes. (Another instrument, in which the stereoı :er consisted of a wide tube sealed on to a graduated ‹ .libratedstem, was first employed, but did not give ı good results). The top

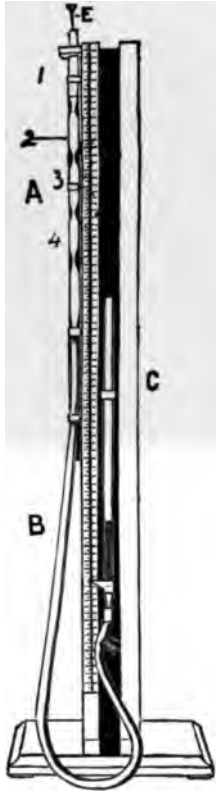

Fig. 6.

of tube A was ground, and could be closed by a small plate of ground glass, which was covered with a thin layer of a mixture of vaseline and bees' wax. By unscrewing the clamps, and adjusting the tube A at the bottom of the stand, the instrument also could be employed with increase of pressure.

The volumes of the several portions of the tube (1, 2, 3, 4) were accurately determined by calibration with mercury. They were as follow :—

1st Instrument: (1) 16·39 cbc.
(2) 10·97 reading on the graduated stem.

2nd Instrument: (1) 15·10 cbc.
(2) 11·06 „
(3) 12·15 „
(4) 10·00 „

In order to test the accuracy of these instruments, the volume of a brass cylinder was determined by their aid, and compared with that found by weighing in water.

To carry out a dilatation experiment the cylinder is placed at the uppermost portion of the tube, the sliding tube adjusted so that the mercury stands exactly at the intersection of the two arms of the etched cross, and the well-greased glass plate then applied, care being taken that the level of the mercury is not altered by this operation. The height of the mercury in the movable tube is then read off on the scale.

The movable tube is then lowered, and adjusted so that the mercury in the other branch is exactly at the level of the second constriction, and the height of the mercury read off as before (in the movable tube). The distance between the two constrictions can be read off once for all, and is, of course, constant. Finally, the height of the barometer is taken.

If

V_1 be the volume of the air in the top compartment of the tube, and

V_2 be the volume of the tube down to the second constriction.

P_1 the height of the barometer in mms.

P_2 the pressure of the air after dilatation, and

x the volume of the cylinder introduced,

then

$$(V_1 - x)P_1 = (V_2 - x)P_2$$

$$x = \frac{V_1P_1 - V_2P_2}{P_1 - P_2} = V_2 - \frac{P_1(V_2 - V_1)}{P_1 - P_2}$$

The volume of the cylinder employed was ascertained by the hydrostatic method to be 11·828 cb. cms.

Experiments with 1st Instrument.

	V_1	V_2	P_1	$P_1 - P_2$	x
(1)	16·39	27·66	762·9	541·2	11·78
(2)	16·39	33·01	762·9	59·3	11·79
(3)	16·39	37·86	762·9	626·9	11·73
				Mean	11·77

The error here is ·06 cbc, or ·5 per cent.

Dilatation experiments with second instrument.

	V_1	V_2	P_1	$P_1 - P_2$	x
(1)	15·10	26·16	764	588·2	11·80
(2)	15·10	26·16	764	588·9	11·82
(3)	15·10	26·16	764	588·3	11·80
(4)	15·10	26·16	764	588·6	11·81
				Mean	11·81

The error here is only ·02 cbc, or ·17 per cent.

The pressure experiments were carried out in a similar manner, the glass plate being secured in its position by the screw E (Fig. 6). In this case, of course, the mercury was set at the lowest constriction, and then forced up to the next, and so on.

P_2 being greater than P_1, and V_1 than V_2, the equation becomes:—

$$x = V_2 - \frac{P_1(V_1 - V_2)}{P_2 - P_1}$$

	V_1	V_2	$P_2 - P_1$	P_1	x
(1)	48·31	38·31	287·7	764	11·75
(2)	48·31	38·31	287·6	764	11·74
(3)	38·31	26·16	644·0	764	11·75
(4)	38·31	26·16	644·4	764	11·76
				Mean	11·75

The error in this case is ·08 cbc, or ·7%.

This form of the apparatus is therefore fairly satisfactory.

The adjustment of the mercury in the constricted portion of the tube can easily be effected, and the capillary error is removed by making all the readings on the wide tube (the diameters of the various constricted portions being approximately equal).

It was found impossible to diminish the pressure to less than about 100 mms., as air then passed rapidly through the walls of the india-rubber tubing, although the latter was specially thick, and had been soaked in paraffin (Cf. Roscoe and Lunt, *Journ. Chem. Soc.* 1889, p. 564).

A few experiments were made to determine the sp. gr. of water by this method, 7·1225 grms. of water at 17° were introduced into the apparatus in a small glass tube of volume = 4·097 grms.

In calculating the results of these experiments it is necessary to allow for the aqueous tension (Cf. *Grassi. loc. cit.*).

As before let V_1, V_2, P_1, P_2 be the actual vols. and pressures. Then

$$x = V_2 - \frac{(V_2 V_1)}{P_2 P_1} P_1$$

For P_1 substitute P^1 = Barometer - Aqueous tension.

Then $P_2 - P^1$ = Bar. - Aq. ten. - diff. of level - (Bar. - Aq. ten.), and the equation becomes

$$x = V_2 - \frac{(V_2 - V_1)P^1}{P_2 - P^1}.$$

The water was freed from air by the air pump.

T = 17° B = 763.

	x Observed.	*x* Calculated.
(1)	7·18	
(2)	7·21	
(3)	7·11	
Mean	7·17	7·132

Error = ·038 = ·53%.

In Grassi's experiments with Regnault's apparatus the error was ·44%.

Another principle of obtaining the volume of a substance, which, so far as we are aware, has never before been applied, is embodied in the apparatus of Fig. 7.

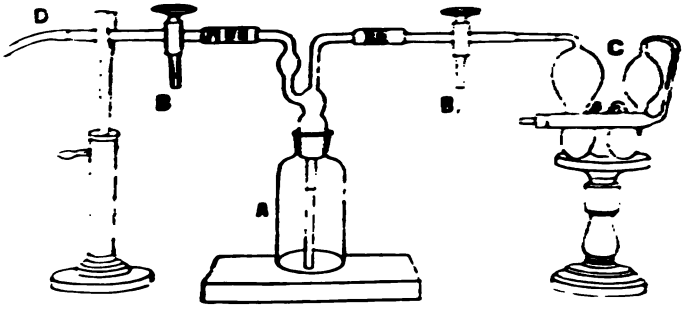

Fig. 7.

The glass vessel A and its tubes up to B and B_1 (Fig. 7) are calibrated. The substance of unknown volume is then placed in A, the air of the vessel displaced by pure, dry carbon dioxide, which is led in at the three-way tap B and out at B_1, and the weight of carbon dioxide in the apparatus determined by sweeping the gas out by a current of dry air passed in at D, and absorbing it in a weighed solution of caustic potash. The vessel A is immersed in water, which keeps its temperature constant, and the latter and the height of the barometer are both noted. From these data the volume of carbon dioxide present is calculated, and hence by subtraction from the known volume of the vessel, the volume of the substance introduced.

The experiments hitherto made show that the volume of carbon dioxide can be easily estimated to within ·3 per cent of its calculated value, no allowance being made for the small proportion of air always present (the gas was generated by the action of diluted hydrochloric acid on marble and dried by sulphuric acid). The following results were obtained by gauging the volume of a vessel by this

method, the volume being altered by the introduction of brass cylinders of known volume :—

Calculated Vol.	Found.	% Error.
279·13	278·7	− ·15
230·47	231·2	+ ·32
277·79	279·1	+ ·47
301·45	301·9	+ ·15
313·27	313·0	− ·09

The method is only adapted to the determination of specific gravities when the volume of the substance bears a large proportion to the whole capacity of the apparatus, as otherwise the experimental error is enormously multiplied.

Taking the last number of the above series for example, we have :—

Vol. of apparatus, 325·1 ; Cylinder introduced, 11.83

Vol. of CO_2 (calctd.)	Found.	*Vol. of Cylinder.* Calctd.	Found.
313·27	313·0	11·83	12·1
Error % = ·09		Error % = 2·28	

Neither this method, nor the ordinary stereometric one can be used for a substance such as glass wool. A long series of experiments made by us with this substance shows that its power of condensing gases on its surface is an insuperable obstacle in the way of the determination of its specific gravity by these methods.

The conclusions to be drawn from our experience of these instruments are :

(1) Their accuracy is inferior to that of the hydrostatic method, which should therefore always be employed when possible.

(2) Porous substances cannot be employed.

(3) The methods of pressure and dilatation should always be both applied.

(4) The air in the stereometer should either be dry or saturated with moisture.

[*Microscopical and Natural History Section.*]

Ordinary Meeting, March 11th, 1891.

Mr. J. COSMO MELVILL, M.A., F.L.S., Vice-President of the section, in the Chair.

Mr. J. DODGSHON was elected a member of the section.

Mr. WATSON, introduced by Mr. ROGERS, made a communication on some experiments he had made on the reproduction of injured or lost limbs in the *Lepidoptera*.

Mr. MELVILL read a paper entitled "An historical account of the genus *Latirus* and its dependencies, with descriptions of eleven new species of *Latirus* (Montfd.), and *Peristernia* (Mörch)."

On the number and formation of many-valued Functions of $x_1x_2x_3 - - x_n$, which of any degree can be constructed upon any Group of those elements, with exhibition of all the values of the Functions. By Thos. P. Kirkman, M.A., F.R.S.

(*Received May 8th, 1891.*)

1. My object in what follows is a double one. One aim is to communicate a new theorem of remarkable power in the search of many-valued functions of n letters, which adds an elegance, though nothing of rigour or completeness, to my solution worked out over thirty years ago, of the Prize-Question proposed at Paris early in 1858 for the competition of 1860.

Another aim is to expand, so as to make them more intelligible to readers not supposed to have seen their way through the preceding chapters, and who know only the simplest elements of the Theory of Groups, the two pages, 342 and 343, of the treatise *On Groups and many-valued Functions*, which this Society did me the great honour to print at once, in Vol. I. Ser. 3, 1862, of its *Memoirs*. To that treatise I shall refer by *M.M.*; and I hope to convince the reader, who knows how to define a substitution and a group, and who can perform the operations in substitutions,

$$AB = C,\ BA = D\ AA = A^2, \&c.,$$

(*M.M.* p. 275), that in the propositions of those two pages is given a complete and demonstrated answer to the above-mentioned Prize-Question of the Institute.

2. The question—what are all the possible groups of n elements?—is exceedingly difficult.

The question—how many distinct functions, with their values, are constructible on the groups when given?—is trivial in comparison with the former.

When I have said what I think needful for the second aim, I have no doubt that my new theorem, although it is nothing but rigorous algebra, will have for the reader, who loves analysis, a charm of magical surprise.

3. The data for the discussion of a definite case of the problem of many-valued functions are three.

First, any system of Q equivalent maximum groups (*M.M.* p. 280, 283, 334) of n elements $x_1x_2x_3 - - x_n$. For these elements let 1 2 3 ... n stand in what follows.

Second, any chosen system Σ of n exponents, not all alike (*M.M.* 57, p. 341), viz.:—

$$n = a_\alpha + b_\beta + c_\gamma + - - - + p_\pi = a + b + c + - - - + p = n ; \quad (1)$$

which is to be read a α's, b β's, c γ's, &c., or a $a$times, β $b$times, γ $c$times, &c., repeated.

Third, an Index group I, determined, as we shall see, by the system Σ.

4. A maximum group G has, and can have, no derived derangement GP = PG (*M.M.* 8, p. 281) by a substitution P. If L be the order of G, *i.e.*, the number of its substitutions, and Q be that of its equivalents (*M.M.* p. 280)

$$G, AGA^{-1}, BGB^{-1}, \&c.,$$

G is also defined as maximum by the condition

$$QL = n!$$

For example of an equivalent ($n = 4$)

1234 = G and	1234 = G′
2341	3142
3412	4321
4123	2413

are equivalent. If 1342 be A, and 1423 be A^{-1}; $1 = AA^{-1}$, $AGA^{-1} = G'$. By the operation AG we get four substitutions, *abcd*; and then the four operations aA^{-1}, bA^{-1}, cA^{-1}, dA^{-1}, give G'. Thus we can always find G' when A and G are given. But we can mostly label and identify our equivalents in practice by far less cumbrous means, than such double operation on the entire column of a group of high order.

We suppose our Q equivalents to be either written out, or so given that we can readily write them out, each in a column or rectangle of L terms, followed by $Q-1$ parallel columns of its $Q-1$ derivates (*M.M.* 7, p. 279), each derivate having L terms, thus:

$$\begin{aligned}
&G_1 + {}_1A_1G_1 + {}_2A_1G_1 + {}_3A_1G_1 + \ldots\ldots + {}_{Q-1}A_1G_1 = N_1;\\
&G_2 + {}_1A_2G_2 + {}_2A_2G_2 + {}_3A_2G_2 + \ldots\ldots + {}_{Q-1}A_2G_2 = N_2;\\
&G_3 + {}_1A_3G_3 + {}_2A_3G_3 + {}_3A_3G_3 + \ldots\ldots + {}_{Q-1}A_3G_3 = N_3; \quad (A_n)\\
&\vdots \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad = \vdots\\
&G_Q + {}_1A_QG_Q + {}_2A_QG_Q + {}_3A_QG_Q + \ldots\ldots + {}_{Q-1}A_QG_Q = N_Q.
\end{aligned}$$

Here N is the group of order $n!$ arranged in Q different ways, being exhausted by each group with its $Q-1$ derivates.

The derivant ${}_rA_s$ of G_s is any substitution not in G_s nor in any previous derivate of G_r. It is thus impossible that two derivates of any group can be alike.

The Q maximum groups are supposed to be so given, that we can readily find in our table (A_n) any one of them, G_r, when presented to us only by a known substitution θ as an equivalent of a known group G_s, as $G_r = \theta_s G \theta_s^{-1}$, or $G_r = \theta_r^{-1} G_s \theta_r$.

How this finding is to be readily done can best be explained when a definite case of our problem is before us.

5. The index-system Σ is

$$\Sigma = \alpha\beta\gamma\gamma\delta\delta\ldots\varepsilon\varepsilon\varepsilon\ldots 0000\ldots; \qquad (2)$$

which is read, one α, one β, two γ's, two δ's, three ε's, &c. This Σ, when we turn our group G into a function Θ, is written over unity in the group that we are placing, as we say, under Σ, and over the first term of every derivate of G.

For $n=5$, Σ may have the following forms only:—

$$\Sigma = \alpha\beta\gamma\delta\delta, \text{ or } \alpha\beta\gamma\gamma\gamma, \text{ or } \alpha\beta\beta\gamma\gamma, \text{ or } \alpha\alpha\beta\beta\beta, \text{ or } \alpha\beta\beta\beta\beta.$$

No two functions $\mathfrak{G}$ and $\mathfrak{G}'$, with their $Q-1$ values each, are allowed as different functions, when one is obtained from the other by a different arrangement of the indices of the same Σ, whether with or without breaking of the repeating clusters $\alpha\alpha$, $\varepsilon\varepsilon$, &c.; much less when one is obtained from the other by altering the numerical values of $\alpha\beta\gamma\ldots$.

It is proved in *M.M.* p. 344, that no additional functions can be won by permuting indices of Σ in $(\mathfrak{A}_n)$.

The proof given in p. 344 is that the writing of $\Sigma' = \alpha\gamma\beta\ldots$ for $\Sigma = \alpha\beta\gamma\ldots$ over $x_1x_2x_3\ldots$ gives no additional function $\Phi = \mathfrak{G}'$. Here is one transposition only made of two different indices. This is proof sufficient, because every permutation of $\alpha\beta\gamma\ldots\nu$ can be effected by a succession of such transpositions. In that page 344, lines 11 and 12, A and B should be A′ and B′; and, in lines 12 and 14 G should be G′, an equivalent of G, namely $\frac{32}{23}G\frac{32}{23}$. *Vide* Note A at the end.

6. The Index group, I_{t+1}, which is always determined by Σ, is of the order

$$t+1 = a!\,b!\,c!\ldots p!. \qquad (3)$$

If $n=6$, I_{t+1} for $\Sigma=\alpha\beta\gamma\gamma\delta\delta$ or $\Sigma=\alpha\beta\beta\gamma\gamma\gamma$, is

$\alpha\beta\gamma\gamma\delta\delta$	$\alpha\beta\beta\gamma\gamma\gamma$
$I_{t+1} = I_4 =$ 123456	or $I_{t+1} = I_{12} =$ 123456
124356	123564
123465	123645
124365	123465
	123654
	123546
	132456
	132564
	132645
	132465
	132654
	132546

of which the orders are 1! 1! 2! 2!, and 1! 2! 3!

The bars under Σ show that the terms in I_{t+1} are purely tactical, the elements being merely permutable positions, not of necessity magnitudes or quantities of any kind; and the terms are not yet algebraic products, such as

$$1^{\alpha}2^{\beta}3^{\beta}4^{\gamma}5^{\gamma}6^{\gamma} + 1^{\alpha}2^{\beta}3^{\beta}5^{\gamma}6^{\gamma}4^{\gamma} + 1^{\alpha}2^{\beta}3^{\beta}6^{\gamma}4^{\gamma}5^{\gamma} + 1^{\alpha}2^{\beta}3^{\beta}4^{\gamma}6^{\gamma}5^{\gamma} +$$

etc., products of powers of $x_1 x_2 x_3 \ldots x_n$.

Such products arise out of the substitutions of a group only when the group is placed, as we say, under Σ, and thus is made suddenly into a function of algebraic quantities.

The Index group is always a woven group (*M.M.* p. 331), in which no element under any repeating cluster ever changes place with one under a different exponent. It is never a grouped group, nor a woven grouped group (*M.M.* p. 304—331). And it is never transitive, *i.e.*, no element can be found in every vertical row.

7. Every group G_n in (A_n) becomes instantly an algebraic function $\mathfrak{G}_n$ of Q values, $\mathfrak{G}_n$ included, when placed under, or, as we say, crowned with, almost any Σ. The very few cases in which the number of values is $<Q$ need not here be noticed.

We need not, in reading a function $\mathfrak{G}_n$, so formed by Σ Q times written, repeat the indices in all the L terms of the rectangle; but we ascribe to every element, from top to bottom of each vertical row, the exponent standing in Σ over the row, and this in each of the Q rectangles. We can thus dictate the function $\mathfrak{G}_n$ and all its $Q-1$ values, which are the $Q-1$ derivates under Σ of G_n. Thus every rectangle of the line G_n under Σ in $(\mathfrak{A}_n)$, is a sum of L products of powers. We often speak of $\mathfrak{G}_n$ and its $Q-1$ values as the Q values of the function $\mathfrak{G}_n$, or of G_n under Σ.

When Σ has κ different exponents, each of our Q equivalents in (A_n) under Σ becomes a Q-valued function distinct from the $Q-1$ others, and the Q^2 values of these Q functions are all different. Thus functions are easily

enumerated and dictated when there are n indices, no one repeated. It is only when some are repeated that difficulties begin; for the number of different functions is then, and then only, $< Q$.

8. Our problem is correctly stated (*M.M.* p. 342), thus: to determine how many of the Q groups G_1 G_2 &c., give, under Σ, distinct Q-valued functions $\Phi_1 = \mathfrak{G}_1$, $\Phi_2 = \mathfrak{G}_2$, &c., of which no function is a value of another.

When our selected Σ is written over the groups of (A_n) and over their derivates, or supposed so written, (A_n) becomes $(\mathfrak{A}_n)$, *i.e.*, A_n under Σ. Our first business is to erase in $(\mathfrak{A}_n)$ all the functions $\mathfrak{G}$ that have fewer than Q values. If $\mathfrak{G}_k$ has fewer, it has $q^{-1}Q$ values ($q > 1$), and $\mathfrak{G}_k$ will be algebraically identical with $q-1$ derivates of G_k under Σ, and will be read in the line of G_k $q-1$ times. Thus simple inspection of $(\mathfrak{A}_n)$ enables us to exclude the $Q-r$ functions that have fewer than Q values; and the remaining r groups of (A_n)under Σ (*M.M.* p. 342, line 1) are all that we have to handle.

It is thus to be understood that when we speak of $(\mathfrak{A}_n)$, we are dealing only with the r functions in it that have Q values.

It will appear in our handling of a definite table (A_n) of maximum equivalents, that this sifting out of the $Q-r$ functions in $(\mathfrak{A}_n)$ that have fewer than Q values, can be done without actually writing out the groups and their derivates; but that G_k above is sufficiently given for this purpose in the form

$$G_k = \phi G_d \phi^{-1},$$

G_d and ϕ being known.

I regret that I did not use in pp. 342, 343, the symbol $\mathfrak{G}_d$ to denote what there is called Φ, the function given by G_d under Σ; nor use Θ and θ for distinction as below used in I_{t+1}.

We read $\mathfrak{G}_d$, "G_d under Σ"; $\theta\mathfrak{G}_d$, "that value which θG_d the derivate of G_d becomes under Σ"; $\theta_s\mathfrak{G}_d\theta_s^{-1}$, "that function which the equivalent $\theta G_d\theta_s^{-1}$ of G_d becomes under Σ." In $\theta\mathfrak{G}_d$ is no operation of θ on $\mathfrak{G}_d$ denoted: such tactical operation on a sum of algebraic products is forbidden, both in the order $\theta\mathfrak{G}_d$ and $\mathfrak{G}_d\theta$.

In solving our problem, then, if we can prove of two groups G_d and G_e in (A_n), that

$$\mathfrak{G}_d = \theta_s\mathfrak{G}_e, \qquad (5)$$

we thus prove that the distinct groups G_d and G_e do not give under our selected Σ distinct functions, because one function is what a derivate of the other group algebraically becomes under Σ, merely by a changed order of elements under the same index.

If, then, G_d is our standard of comparison, we are bound by (5) to mark G_e out of our table (A_n), as useless to us under our selected Σ.

We come to handle G_d thus. Having our I_{t+1}, which is determined by our selected Σ, written in a column as in art. 6, we seek a group in (A_n) which has $m+1$ substitutions in common with our index-group under the barred Σ, so that no group has more than $m+1$ of them. Many G's may have such a greatest subgroup J_{m+1} in common with I_{t+1}. We take one, G_d. Let the subgroup be

$$J_{m+1} = 1 + \Theta_1 + \Theta_2 + \ldots + \Theta_m; \qquad (6)$$

We find these Θ's in I_{t+1}, and name them so where they stand in it. Its remaining $t-m$ substitutions we call its θ's, none of which is in G_d, which has all the Θ's. I_{t+1} can be written thus:

$$I_{t+1} = 1 + \Theta_1 + \Theta_2 + \ldots + \Theta_m + \theta_1 + \theta_2 \ldots + \theta_{t-m}; \qquad (7)$$

9. The next proposition in *M.M.* p. 342 is double, affirming what had been proved in preceding pages.

$$\mathfrak{G}_d = \mathfrak{G}_d\theta_1; \text{ and } \mathfrak{G}_d = \mathfrak{G}_d\Theta_1; \qquad (8)$$

whichever among the above-written be Θ_1 or θ_1.

The second is clearly true; because, Θ_j being in G_d,

$$G_d\Theta_j = G_d,$$

and this identity can be placed under any Σ.

The former has to be proved in spite of the inequality

$$G_d \pm G_d\theta_i,$$

a true negation, because θ_i is not in G_d, and no group is identical with its derangement by a substitution not in the group.

But this required demonstration of the first is easy, if it be granted that when two substitutions to be multiplied together are placed under barred Σ, and the product is equated to the tactical result under barred Σ, that equation, if the bars are at once suddenly removed, must be algebraically true.

Let H be any substitution of the group G_d, and let θ_i be any substitution of the index-group which is not in G_d, also let barred Σ be written over both H and θ_i.

We have to perform, without regard to exponents, by the rule for sinister multiplication (*M.M.* art. 3, p. 275) the operation

$$\bar{\bar{H}}\cdot\bar{\bar{\theta}}_i = \bar{\bar{K}}.$$

Looking now at the clusters under the repeated indices of Σ, we see that, by the rule, the final cluster on the right of H is deposited in K in the places and order of the final cluster of θ_i, as well as, by the form of I_{t+1} (art. 6), under the final cluster of unity. But what change, if the bars be at the same moment removed, has been made in the algebraical value of that final cluster, in unity, in θ_i or in H, by its reading in K? None; the cluster is in all four the same product of powers. The like is true of the eth cluster, whatever it be. We have nothing before us but

$$\mathfrak{H}\theta_i = \mathfrak{H},$$

where the left member stands only for what the derangement $H.\theta_i$ becomes under Σ.

Or thus: let the reader write over $1\,2\,3\,..\,n$ any Σ he pleases; under that unity let him write any permutation θ_i he pleases made within the clusters, so as to exchange no two elements not in the same cluster, and therefore not carrying the same index. Let him now write any permutation whatever of the n elements, calling it H; and next let him perform, without regard to indices, the tactical operation $H\theta_i$ upon θ_n and call the result K. If, now, he writes over both H and K his selected Σ, he will find them algebraically identical.

Hence, it is clear, that if every substitution of G_d in turn be taken for H, we have it demonstrated that

$$\mathfrak{G}_d = \mathfrak{G}_d\theta_i; \qquad (9)$$

whichever among the $t-m$ θ's of I_{t-1} θ_t may be.

10. The two sides of (9) are the same rectangle of L products of powers. No man, therefore, will deny that, if both sides be multiplied by unity, their algebraic identity will remain visible. Let us multiply (9) on left and right by

$$1 = \theta_i\theta_i^{-1}.$$

We get

$$\mathfrak{G}_d = \theta_i(\theta_i^{-1}\mathfrak{G}_d\theta_i) = \theta_i\mathfrak{G}_r, \qquad (10)$$

whichever of the θ's of I_{t+1} θ_t may be; where G_r is a group to be readily found in $(A)_n$, art. 4, by the known θ_i and the known G_d, in the definition

$$G_r = \theta_i^{-1}G_d\theta_i, \qquad (11)$$

and (10) reads, G_d under Σ is algebraically identical with the derivate θ_iG_r under Σ of the given group G_r.

That θ_iG_r is a derivate of G_r, follows from the truth that, as θ_i is not in G_r (for if it were (11) would give

$$\theta_iG_r\theta_i^{-1} = G_r = G_d, \text{ Q.E.A.})$$

but is in N_r in (A_n), it must occur in some derivate of G_r; and that derivate, whether θ_i be or be not the first of its L substitutions, is the derivate θ_iG_r of G_r (*M.M.* p. 280).

Now, the derivate under Σ of any group G_e has instantly become under Σ a value of $\mathfrak{G}_e$, *i.e.*, of G_e under Σ.

Equation (11) represents $t-m$ groups,

$$G_{e1}=\theta_1^{-1}G_e\theta_1;\ G_{e2}=\theta_2^{-1}G_e\theta_2,\ G_{e3}=\theta_3^{-1}G_e\theta_3,\ +\ \&c.\ ; \qquad (12)$$

to which correspond $t-m$ equations

$$\theta_1\mathfrak{G}_{e1}=\mathfrak{G}_e,\ \theta_2\mathfrak{G}_{e2}=\mathfrak{G}_e,\ \theta_3\mathfrak{G}_{e3}=\mathfrak{G}_e,\ \&c. \qquad (13)$$

among which is the above, (10),

$$\mathfrak{G}_e=\theta_1\mathfrak{G}_{e1}.$$

Whether these $t-m$ groups (12) G_{e1}, G_{e2} . . . $G_{e(t-m)}$ are all different, we shall discover presently. We shall see that there are only $t'<t-m$ of them different. Hence we are bound to mark out this G_{e1} from our table (A_n), along with $t-m-1$ others, as in art. 8 under (5).

11. This we may conceive as follows. Our standard group G_d comes forward with equations 12 and 13 in his hand, to make $t-m$ charges against certain of our Q equivalents in (A_n). The charge in each case is, that the accused under Σ has a value algebraically identical with $\mathfrak{G}_d$.

We ask—which of the $Q-1$ groups do you first call up? G_d answers—"my first equivalent by θ_1, $\theta_1G_d\theta_1^{-1}$." We look into (A_n) and remark—that is our group G_f; which of the values of $\mathfrak{G}_f$ do you accuse? "That given by the derivate under Σ, θ_1G_f." We examine that, and see that, under Σ, θ_1G_f is nothing else algebraically than the L products of G_d. We, therefore, write d opposite in the line G_f, to show that G_f has been expelled by the standard G_d.

In the same way we proceed to listen to G_d's other charges, and are compelled by the truth of them to mark out with d a number of other groups in (A_n). Presently, we hear a like accusation against $\theta_mG_d\theta_m^{-1}$, and on finding it we exclaim,—that is our friend G_f again. "Very likely," says G_d, "look at the derivate θ_mG_f." We look, and see that it is none other than θ_1G_f above found, a derivate con-

taining both θ_1 and θ_m, so that $\theta_1 G_f = \theta_m G_f$, is under Σ, the same column of L products.

If

$$\theta_1 \mathfrak{G}_f = \mathfrak{G}_d \text{ and } \theta_m \mathfrak{G}_f = \mathfrak{G}_d$$

were two values of $\mathfrak{G}_f$ obtained from two different derivates of G_f, the function $\mathfrak{G}_f$ having two values alike would have fewer than Q values, which is contrary to our hypothesis in article 8.

We deposit a second d in the line G_f, and are prepared for the necessity of writing a third d if it arises.

After hearing the $t-m$ charges of G_d, we find the number t' of different groups, marked out by them, to be less than $t-m$. We then release G_d with thanks from the post of standard.

What the exact number t' is, it would be a question no less absurd to reply to in general symbols than to ask. We are handling perfectly general terms, where n and Σ are anything you please, so that their meaning remains the same during our discussion of table (A_n) of definite equivalents. The author of the two pages proved himself to be something of a dunce, in forsaking the path of symmetric analysis, in order to turn his clear $t-m$ into something clearer. The talkee about t' and t_1 does neither good nor harm, and the 'we conclude' (article 59) is nothing more than the wise decision, that, p and t' being neither of them either given or found,

$$\frac{p}{t'+1} = t' + 1.$$

We can predict, with assurance, that when our work is done on our table (A_n), every t' for every standard under every Σ will be exactly recorded in it, and numerically given when G_1, G_2, &c., are actual groups, and not mere symbols.

12. Our next step is to select from the unmarked equivalents in (A_n) any group G_d that has, in common with

our unaltered I_{t+1}, determined by our unchanged Σ, a largest subgroup J_{m-v+1}, ($v \overline{\overline{>}} 0$), of $m-v+1$ substitutions. These we find in I_{t+1}, and name them where they stand. So that our index group is now, ($v \overline{\overline{>}} 0$),

$$I_{t+1} = 1 + \Theta'_1 + \Theta'_2 + \ldots + \Theta'_{m-v} + \theta_1 + \theta_2 + \ldots + \theta_{t-m+v} \qquad (14)$$

We care not to enquire whether or no, if $v=0$, our new Θ's, and therefore our new θ's, are identical with our former (6) in J_{m+1} and G_d. For even if they are the same, the equivalents

$$\theta_1 G_{dd} \theta_1^{-1},\ \theta_2 G_{dd} \theta_2^{-1},\ \&c.,$$

that we shall have to handle and mark out, will not be the same that

$$\theta_1 G_d \theta_1^{-1},\ \theta_2 G_d \theta_2^{-1},\ \&c.,$$

were in equation (12), because we know that G_d and G_{dd} are different groups in (A_n).

Our new standard G_{dd} next prefers his charges against $t-m+v$ of our unmarked equivalents in (A_n), from the equation

$$\mathfrak{G}_{dd} = \theta_i(\theta_i^{-1}\mathfrak{G}_{dd}\theta_i) = \theta_i \mathfrak{G}_{ee},$$

for every θ in I_{t+1}. These are verified by inspection and recorded by $d,^2$ as before by d, in the proper places. G_{ddd}, G_{dddd} . . . may in turn become standards, and do the like on the yet unmarked groups in $(A_n \cdot \cdot)$. By the increase of v we get at last $m-v=0$. There is now no Θ in I_{t+1}; no unmarked group in (A_n) has more than unity in common with I_{t+1}, which is now

$$I_{t+1} = 1 + \theta_1 + \theta_2 + \ldots + \theta_r. \qquad (15)$$

We choose any unmarked group G_D for standard, and have to hear t charges brought by it, one for every θ in (15), from the equation

$$\mathfrak{G}_D = \theta_i(\theta_i^{-1}\mathfrak{G}_D\theta_i) = \theta_i \mathfrak{G}_E, \qquad (16)$$

against groups yet unmarked in (A_n). The requisite outmarkings are made by D in the proper places.

If there are still unmarked equivalents in (A_n), they must be $h(t+1)$ in number: for if not, our last standard G_Δ will find that two or more of the groups that he accuses, defined by θ_k and θ_m . . . , are the same one in our table (A_n). Let us suppose that

$$\theta_k G_\Delta \theta_k^{-1} = \theta_m G_\Delta \theta_m^{-1} \qquad (17)$$

are identical. It follows that

$$\theta_m^{-1}\theta_k G_\Delta = G_\Delta \theta_m^{-1}\theta_k, \quad i.e.$$

$$\theta_p G_\Delta = G_\Delta \theta_p, \qquad (18)$$

because in, I_{t+1}, $\theta_m^{-1}\theta_k = \theta_p$.

This (18) is possible only on condition either that

$$\theta_p G_\Delta = G_\Delta = G_\Delta \theta_p,$$

showing that θ_p is in G_Δ, or that $\theta_p G_\Delta$ is a derived derangement of G_Δ. The first is absurd, because G_Δ has no substitution of I_{t+1} but unity. The second is absurd, because G_Δ is a maximum group. Therefore the unmarked groups in (A_n), from which we have to choose G_D, G_{DD} . . . G_Δ, are in number $h(t+1)$.

Therefore all the t groups accused by G_Δ will be found distinct among the unmarked in (A_n). We mark out each with a Δ; and there are now no groups unmarked in our table, besides our standards

$$G_1 G_{\Delta\Delta} G_{\Delta\Delta\Delta} \ldots G_D G_{DD} \ldots G_\Delta.$$

If the number of these is R, we have learned how to construct R distinct many-valued functions under the same Σ, and by help of the same index-group I_{t+1}.

The number of groups marked out as useless under this Σ is $Q-R$, which carry the marks d, d^2, d^3 . . , not of necessity in equal numbers, where Q is the r of *M.M.* p. 342.

We have it now in our power to dictate, with all their values, R different functions, of which no one is a value of

another, from the above groups G_α, $G_{\alpha\beta}$, &c., in our table under Σ, which are turned by that Σ into the functions

$$\mathfrak{G}_\alpha\mathfrak{G}_{\alpha\beta}\mathfrak{G}_{\alpha\beta\gamma}\ldots\mathfrak{G}_\beta\mathfrak{G}_{\beta\gamma}\ldots\mathfrak{G}_\gamma$$

The above *proof* that no two of G_Δ's t charges fell on the same group, is equally valid concerning the t charges of $G_\beta G_{\beta\gamma}\ldots$ The reader may ask, why not valid concerning the $t-m$ charges of G_α, or the $t-m+\tau$ charges of $G_{\alpha\tau}$, &c. The *reason* is, that when there is no θ, there can be none of the reductions of the form (*M.M.* p. 342, in the equation below (*e*))

$$\mathfrak{G}_\alpha\theta_\alpha = \mathfrak{G}_\alpha\theta_\beta\theta_\alpha = \mathfrak{G}_\alpha\theta_\beta, \text{ &c.,}$$

in which we are to remember that $\mathfrak{G}_\alpha\theta_1 = \mathfrak{G}_\alpha$, and that I_{t+1} contains θ_j, the product $\theta_i\theta_j$.

13. We have now, retaining our table (A_n) cleared of outmarkings, to choose another Σ, which will determine another index-group I_{t+1}. The processes for determining the number of distinct functions that our table (A_n) will give under its new Σ, are in all things the same as above in art. 8, &c.; and thus we can obtain all possible many-valued functions constructible on (A_n) under every different Σ.

If we then proceed so to deal with every other table of maximum equivalent transitive groups of n elements, we shall obtain, without omission or repetition, the entire number with all their values, of functions possible of n letters that cannot be obtained as products of smaller functions. There are always, for $n>5$, several, and very soon many, maximum transitive groups of various orders $<\frac{1}{2}n!$

We have next to consider the number of terms in our won functions. This is determined in *M.M.* p. 343, by the comparison of $\mathfrak{G}_\alpha$ with G_α.

It may also be shown as follows:—

Since J_{m+1}, common to G_α and I_{t+1}, is

$$J_{m+1} = 1 + \theta_1 + \theta_2 + \ldots + \theta_m, \qquad (a)$$

a subgroup of G_d, we can write

$$G_d = J_{m+1} + P_1 J_{m+1} + P_2 J_{m+1} + \ldots + P_{l-1} J_{m+1}, \qquad (b)$$

where $l.(m+1) = L$ is the order of G_d, which under Σ is

$$\mathfrak{G}_d = \mathfrak{J}_{m+1} + P_1 \mathfrak{J}_{m+1} + P_2 \mathfrak{J}_{m+1} + \cdots + P_{l-1} \mathfrak{J}_{m+1}; \qquad (c)$$

here by $P_s \mathfrak{J}_{m+1}$ is meant what $P_s J_{m+1}$ becomes under Σ.

It is plain that, in I_{l+1} under its Σ, all the $l+1$ products are algebraically identical. Wherefore

$$\mathfrak{J}_{m+1} = (m+1)\mathfrak{P}_0. \qquad (a)$$

is the first term on the right of (c), $\mathfrak{P}_0$ being unity under Σ.

To find by an example the other terms of (c), let

$$n = 4, \ \Sigma = \alpha\alpha\beta\beta, \ L = l.(m+1) = 2 \cdot 4,$$

and let

$$\begin{aligned} G_d = {} & 1234 \ \ 3412 = J_{m+1} + P_1 J_{m+1}; \ (P_1 = 3412). \\ & 2143 \ \ 4321 \\ & 1243 \ \ 3421 \\ & 2134 \ \ 4312 \end{aligned}$$

Then we have

$$\begin{aligned} \mathfrak{G}_d = {} & \begin{matrix} \alpha\alpha\beta\beta & \alpha\alpha\beta\beta \\ 1234 & 3412 \end{matrix} = \mathfrak{J}_{m+1} + P_1 \mathfrak{J}_{m+1}, \qquad (c) \\ & + 2143 + 4321 \\ & + 1243 + 3421 \\ & + 2134 + 4312 \end{aligned}$$

i.e. $\mathfrak{G}_d = 4 \cdot (1^\alpha 2^\alpha 3^\beta 4^\beta + 3^\alpha 4^\alpha 1^\beta 2^\beta) = (m+1)(\mathfrak{P}_0 + \mathfrak{P}_1), \ (\beta \geqq 0).$

or every term in $\mathfrak{G}_d$ is $(m+1)$ times repeated; so that, if G_d has L terms, the number of different products in the function $\mathfrak{G}_d$ is always $L : (m+1), \ (m \geqq 0)$; and every value of $\mathfrak{G}_d$ has the same number of products.

It is not to be supposed that, in obtaining the equivalents in (A_n) that we compare, we have to operate on entire columns of substitutions. In all cases the groups of our table (A_n) can be labelled, in many cases by three substitutions at most, and frequently by one (l) only, so that, instead of the column $\theta G \theta^{-1}$, $\theta l \theta^{-1}$ in one line often suffices for

definition and identification. Thus the work goes rapidly on.

There is an inelegance in the repeated out-markings which cannot be avoided in the symmetrical handling of the subject in perfectly general terms; but in practice this inelegance completely disappears. In all the definite cases that I have studied, of $n<9$, the Index-group can be so written as a product of two or more groups, that, by using *not* all the θ's, but only the substitutions of a factor group, we can avoid all repetition of outmarkings. The inelegance affects not the validity of the preceding symmetrical general demonstration.

On these transformations of the Index-group, it would be useless to say more until we have a definite table (A_n) before us. I have worked through many such tables, and hope to present the results to this Society.

14. I may now exhibit my new theorem. Let G_d be our standard group, and θ_a be any substitution of the index-group determined by our Σ, which θ_a is not a substitution of G_d. Let

$$G_e = \theta_a G_d \theta_a^{-1} \qquad (a)$$

be an equivalent of G_d which contains, not θ_a, but an equivalent $\theta_a J_{m+1} \theta_a^{-1}$ of the subgroup

$$J_{m+1} = 1 + \Theta_1 + \Theta_2 + \ldots \Theta_m \quad (m \geq o),$$

which is common to G_d and our index-group I_{t+1}.

Let $G_d \cdots$ and $G_e^{+} \cdots$ stand for the two lines in our table (A_n), which exhibit G_d and G_e with their $Q-1$ derivates, and let $\mathfrak{G}_d^{+} \cdots$ and $\mathfrak{G}_e^{+} \cdots$ stand for those lines under Σ, viz., for the functions $\mathfrak{G}_d$ and $\mathfrak{G}_e$ followed by their $Q-1$ values. Then is

$$G_e^{+} \cdots = G_e + {}_1A_e G_e + {}_2A_e G_e + \cdots {}_{f-1}A_e G_e + {}_fA_e G_e + {}_{f+1}A_e G_e + \cdots + {}_{q-1}A_e G_e = N_e; \qquad (b)$$

which by (a) is

$$G_e^{+} \cdots = \theta_a G_d \theta_a^{-1} + {}_1A_e \theta_a G_d \theta_a^{-1} + \cdots + {}_{f-1}A_e \theta_a G_d \theta_a^{-1} + {}_fA_e \theta_a G_d \theta_a^{-1} + {}_{f+1}A_e \theta_a G_d \theta_a^{-1} + \cdots = N_e; \qquad (c)$$

Since θ_a^{-1} is in N_s and not in G_s, it must be in some derivate of G_s; let this be $A_s G_s$ in (b): then we read, art. 10,

$$_fA_s\theta_a = \theta_a^{-1}\theta_a = 1, \text{ in } (c). \qquad (d)$$

Wherefore (c) becomes

$$G_s^{\dagger\cdots} = \theta_a G_d \theta_a^{-1} + {}_1A_s\theta_a G_d\theta_a^{-1} + \cdots {}_{f-1}A_s\theta_a G_d\theta_a^{-1} + G_d\theta_a^{-1} + {}_{f+1}A_s\theta_a G_d\theta_a^{-1} + \cdots = N_s; \qquad (e)$$

The left multipliers of G in (b) are

$$1, {}_1A_s, {}_2A_s, \cdots {}_{f-1}A_s, {}_fA_s, {}_{f+1}A_s, \cdots {}_{q-1}A_s.$$

The left multipliers of G_d in (c) are

$$(1, {}_1A_s, {}_2A_s, \ldots {}_{f-1}A_s, {}_fA_s, {}_{f+1}A_s + \ldots {}_{q-1}A_s)\theta_a,$$

or the preceding each multiplied on the right by θ_a.

We know that the first set are all different by article 4; therefore, the second set θ_a, $_1A_s\theta_a$, &c., are all different, and consequently, by (d), all the sinister multipliers of G_d in (e) are different.

Put now $G_s^{\dagger\cdots}$, in (e) under Σ; it becomes

$$\mathfrak{G}_s^{\dagger\cdots} = \theta_a \mathfrak{G}_d \theta_a^{-1} + {}_1A_s\theta_a \mathfrak{G}_d\theta_a^{-1} + \cdots {}_{f-1}^{\dagger}A_s\theta_a \mathfrak{G}_d\theta_a^{-1} + \mathfrak{G}_d\theta_a^{-1} + {}_{f+1}A_s\theta_a \mathfrak{G}_d\theta_a^{-1} + \ldots = N_s \qquad (f)$$

We have demonstrated in article 9, equation (9),

$$\mathfrak{G}_d = \mathfrak{G}_d\theta_i = \mathfrak{G}_d\theta_a^{-1}. \qquad (g)$$

For θ_i in article 9 means any θ, *e.g.*, θ_a^{-1}, of the index-group, whereby (f) becomes my new theorem,

$$\mathfrak{G}_s^{\dagger\cdots} = \theta_a \mathfrak{G}_d + {}_1A_s\theta_a \mathfrak{G}_d + \cdots + {}_{f-1}A_s\theta_a \mathfrak{G}_d + \mathfrak{G}_d + {}_{f+1}A_s\theta_a \mathfrak{G}_d + \cdots {}_{q-1}A_s\theta_a \mathfrak{G}_d = \mathfrak{G}_d^{\dagger\cdots} \qquad (h)$$

This is $\mathfrak{G}_d^{\dagger\cdots}$ in an order different from that of $G_d^{\dagger\cdots}$ under Σ in table (A_s). We see $\mathfrak{G}_d$ and $Q-1$ values of it, the values of $Q-1$ different derivates of G_d; for we have proved that these derivates are made by $Q-1$ multipliers of G_d, as different from each other as are those of G_s in (A_s).

Thus in (h) it is demonstrated of G_d and G_s in (a) that

$$\mathfrak{G}_s^{\dagger\cdots} = \mathfrak{G}_d^{\dagger\cdots},$$

and the charges brought by the standard G_d against certain of its equivalents in what precedes, instead of being, that each had under Σ a value algebraically identical with $\mathfrak{G}_d$ might as truly have been, that none had a value not a value of $\mathfrak{G}_d$, or lacked any value of $\mathfrak{G}_d$. But I am not sure that the wider form of the charges made would better have fixed the ideas of the student. Certainly it would have made no difference in the steps of demonstration or in the result concerning the number and definitions of functions to be found.

15. No allusion to groups was made in the Question proposed by the Academy of Paris, in 1858, for the competition of 1860.

"Quels peuvent etre les nombres de valeurs des fonctions bien définies, qui contiennent un nombre donné de lettres, et comment peut on former les fonctions pour lesquelles il existe un nombre donné de valeurs?"

I soon discovered, on making in 1859 my first acquaintance with groups and their functions, that the groups were themselves the functions. All possible finite functions of n letters with their $\frac{n!}{k}$ values, k being the order of any group. G of n elements, are before us when every G is written out with its $\frac{n!}{k}-1$ derivates under every Σ in turn. If G is maximum, $n!=kQ=LQ$, as in article 4. If G of order k is not maximum, it is a subgroup g of some maximum G', whose Q columns under Σ, each of L products, have for equal subdivisions the $\frac{n!}{k}$ values of the subgroup g, one subdivision being g. And these $\frac{n!}{k}$ values can be dictated from those Q columns of the maximum G', which G' can be written $(k(l\times 1)=L)$,

$$G'=g+a_1g+a_2g+\ldots+a_lg.$$

Thus it was clear to me that, to attempt to answer

questions about many-valued functions before the study and formation of their groups, was to put the cart before the horse.

I have most convincing proofs that in the very highest places of European science, this cart before the horse is analytical orthodoxy. Again and again I have been told by mathematicians of the foremost repute in foreign seats of learning, where these subjects are really studied, that what I have done in groups, in the *Memoirs* and *Proceedings* of this Society, will be very useful when once we have learned how to form the right functions. Functions before Groups is the opinion in fashion; one can then amuse one's self by finding the groups.

In English, I have never even indirectly heard one word of any opinion on my handling of either groups or their functions.

The cart before the horse is certainly the correct method, where you prefer pottering behind an orthodox wheelbarrow to doing the work like an Englishman.

16. The only result in these functions for $n > 5$ that I know of, as won in the path of genuine orthodoxy, is the six-valued function of six letters given in the admirable *Algèbre Supérieure* of M. Serret, p. 515, Paris, 1854. Its form is a product in one line of five similar factors, one of which is $(ab+cd+ef)$.

The Academy, after this success in 1854 of one of their most eminent members, were naturally desirous, in 1858, to encourage further effort in the same orthodox direction. That *Algèbre* says nothing of groups.

In this year, 1891, I have, for the first time, had the courage to unpack and lay in readable order all the contents of this hard little bale of M. Serret. I have found in it eight functions,

$$AA'A''BCDD'E.$$

A, as well as each of its duplicates, A′ and A″, is a one-valued function of six terms.

B is a one-valued function of 15 terms.

C is a one-valued function of 60 terms: freed from the common multiplier *abcdef*, C is the sum of 60 triplets, $a^\alpha b^\beta c^\beta$, &c.

D, as well as its duplicate D′, is a six-valued function of 60 terms under $\Sigma = \alpha\beta\gamma\gamma\delta\delta$.

E is a six-valued function of 30 terms under $\Sigma = \alpha\alpha\beta\beta\gamma\gamma$.

Of the 243 terms of this six-valued product of five factors, 153 are wasted on a tight and baffling twist of useless symmetricals and duplicates.

The function D is my Y (*M.M.* p. 351), and the function E is my U, (p. 352).

These functions, U and Y, are read in my pages, along with the full tale of the eleven other possible six-valued functions of six letters; they are not hidden away in clumsy packing, out of sight and guessing, but are all really given with their values, rapidly readable in the columns of the six equivalent maximum groups, one of which, J (p. 350), is fully written out; the others being given in the same page as its equivalents. All the functions given in my § 11. (p. 344), are "des fonctions bien définies," of the Prize-question. How far my complete accounts of the possible functions of four and of five letters were new, I know not.

All this over 30 years ago. A forgotten story now. I have had the sense, of course, to keep my peace. For, in these islands, a thinker has often to be content with "audience fit though few," himself, and his guardian angel. We have had some private fun together; but is it very wicked in me to be heard laughing one little laugh before I die?

The Academy were not content, and saw no reason to award their prize. I thought, 30 years ago, that I had done

with demonstration the work required. And to-day, heretic that I am, I actually believe that I had done it all. The Academy have never denied this. But the Academy were not content. Would you know why? Well, look at the shocking way in which I did it all; so utterly destitute even of the vulgar grace of orthodoxy! Nowhere—nowhere was my cart ever seen trotting before my horse!

17. To sum up. For this problem of many-valued functions we require the necessary *data*, and the necessary algebra.

We have the first when there is before us a table (A_n) of Q equivalent maximum groups $G_1 G_2 \dots G_Q$ made with n elements, with all their derivates.

By writing over the Q columns of each line any the same selected Σ, we turn them into $\Theta_1{}^{+\cdots}, \Theta_2{}^{+\cdots}, \dots \Theta_Q{}^{+\cdots}$; Q functions with all their values. It is easy by art. 8 to reduce the Q functions in (Θ_n) to $r < Q$, which have all under the chosen Σ Q values. We have only to determine how many of these r are distinct functions $\Theta_1{}^{+\cdots}$, &c.

Form the index-group I_{t+1} given by Σ. Take any one G_d of the r groups, and to the $m+1$ substitutions $(m \geqslant 0)$ in I_{t+1} which are also in G_d, give in I_{t+1} the names $1, \theta_1, \theta_2, \dots \theta_m$; naming the other $t-m$ substitutions of I_{t+1}, $\theta_{t}, \theta_{t} \dots \theta_{t-m}$. Let θ_s stand for any one of these $t-m$.

The algebra is completed by—

$$\Theta_d = \Theta_d \theta_s = \theta_s(\theta_s^{-1} \Theta_d \theta_s) = \theta_s \Theta_f,$$

where $\Theta_d \theta_s, \theta_s^{-1} \Theta_d \theta_s, \theta_s \Theta_f$, stand for nothing but what $G_d \theta_s$, $\theta_s^{-1} G_d \theta_s$, $\theta_s G_f$, become under Σ.

We find G_f in our table (A_n) and mark it out by a d, as useless, because the value $\theta_s \Theta_f$ is identical algebraically with Θ_s. And we have $t-m$ such outmarkings with d to perform, one for every θ_s. We have then done with G_d: Θ_d is one of our sought functions.

We take next any group $G_{d'}$ in (A_n) which is not marked

out by d, and we deal with L_{n-2} compared with $G_{n!}$ just as we dealt with it ($n>5$) compared with G_n. We have next to mark out, by d^2 $(t-m)$ times, other groups, each of which gives a function that has a value identical with G'_n. The same group may be more than once marked by d, and more than once by d^2; it matters not for how many reasons we reject it as useless under Σ. We have now done with $G_{n!}$ and $G_{n!}$ is one of our sought functions.

We take next any group $G_{n!}$ that is not marked out either by d or d^2, and repeat the same process till there is no group in our table (A_n) that is not marked out, except

$$G_d,\ G_{d^2},\ G_{d^3},\ \&c.,$$

that we have handled and done with.

If there are R of these so done with, our table (A_n) has given us R distinct Q-valued functions G_n &c., all under the same Σ, which will differ in the number of their terms, (article 13).

When we have thus used every Σ under which r groups in $(\mathfrak{A}_n)$ have Q values, and have dealt in like manner with every table (B_n) (C_n) &c., of which there are always more than one for $n>5$, of equivalent maximum transitive groups, we have found, and can dictate with all its values, every possible finite many-valued function of n letters (as shown in article 15), which is not a mere product of simpler functions.

The cases of Σ under which $Q-r$ groups in our tables $(\mathfrak{A}_n)$ &c., give functions of fewer than Q values, are all simple, and the $Q-r$ are easily laid aside. The proof will appear in practice upon definite values of n, the number of letters to be handled.

I have tacitly assumed in what precedes, that there is no k-valued whole and rational function of n letters that cannot be formed by writing a certain Σ over a group and its $k-1$ derivates. Instead of piling up words to prove this negative, I content myself with promising that, being given

any one value, F_n, of a k-valued function F of n letters, I will so write F_n that, when exponents are all effaced, it shall be exactly a group containing unity, whose derivates under Σ just effaced shall be the remaining $k-1$ values of F.

I am inclined to believe that the only datum really necessary for the finding all such functions F, whatever they may be, is one only written out of the Q equivalent maximum groups, say the cyclical group containing $234\ldots(n-1)\,n\,1$; but, that the method from such datum, if practicable, would be briefer in exposition and easier in practice than that given in the preceding expansion of *M.M.* pp. 342, 343, requires to be proved.

[*Physical and Mathematical Section.*]

Annual Meeting March 11th, 1891.

JAMES BOTTOMLEY, B.A., D.Sc., F.C.S., President of the Section, in the Chair.

The Treasurer's accounts for the year 1890–91 were presented, and showed :—Balance from last year, £3. 19s. 7d., cash received during the current year £4. 10s. 4d., making a total of £8. 9s. 11d. ; against which were payments during the current year £5. 3s. 7d. ; leaving a balance in favour of the Section of £3. 6s. 4d.

It was moved by Mr. WM. THOMSON, seconded by Mr. J. A. BENNION, and resolved :—"That the Treasurer's accounts be received and passed."

The following gentlemen were elected officers of the Section for the ensuing year :—

President—J. A. BENNION, M.A., Barrister-at-Law.

Vice-Presidents—JAS. BOTTOMLEY, B.A., D.Sc., F.C.S. ; WM. THOMSON, F.R.S.Ed., F.C.S., F.I.C.

Secretary—T. W. BROWNELL, F.R.A.S.

Treasurer—JOHN ANGELL, F.C.S., F.I.C.

The following constitute the Section :—

Members—JOHN ANGELL, F.C.S., F.I.C. ; JAMES BOTTOMLEY, B.A., D.Sc., F.C.S. ; T. W. BROWNELL, F.R.A.S. ; F. J. FARADAY, F.L.S., F.S.S. ; A. HODGKINSON, M.B., D.Sc. ; WM. MATHER, M.P. ; WM. THOMSON, F.R.S.Ed., F.C.S., F.I.C. *Associate*—J. A. BENNION, M.A.

Notes on the Geological section exposed in the Railway Cutting from Levenshulme to Fallowfield. By Wm. Brockbank, F.G.S., F.L.S., and C. E. de Rance, Assoc. Inst. C.E., F.G.S., F.R.G.S., F.R.M.S., of H.M. Geological Survey.*

(*Received January 27th, 1891.*)

PART II.

It was intended to have dealt with the Permian strata in this communication, but since Part I. was laid before you, a very important exposure of the beds, lying below those described on that occasion, has been disclosed by the cutting of a sewer on the south side of the railway, which has proved the Upper Coal Measures to extend eastward to a distance of 1,072 feet, from Slade Lane Bridge, and it appears desirable to complete this portion of the subject before entering into the details observed of the later formations, and also to compare the results obtained as to the thickness and character of the Upper Coal Measures exposed in the section, with those proved in borings in the Manchester District, and the same sub-formation elsewhere, and the bearing of the facts observed on the probable mode of deposit of these very interesting beds.

The beds exposed in the section described in our last communication, amount to a vertical thickness of 230 feet, and contain eight groups of limestone of a united thickness of 30 feet, but, eliminating the marl and shale partings, the thickness of pure limestone is 24 feet, down to the base of the eighth group.

* Communicated with the permission of the Director General.

The beds since exposed extend eastwards, towards the London and North Western Railway, for a distance of about 734 feet, the average dip is about 16 degrees, the maximum inclination being to the S.W., or an angle to the line of railway, the thickness of the beds exposed is not less than 244 feet. They consist of bright purple marls occasionally mottled.

The most interesting portion of the section discloses the following beds in descending order :—

	ft.	in.	
Red marls	56	0	
Mottled marls	1	6	
Limestone (No.IX)	0	10	
Mottled marls	2	0	
Purple marls	2	0	244
Hard red shale	0	7	
Limestone nodules	0	3	
Light purple marl	0	8	
Indurated green marl	0	11	
Purple marls	180	0	

The number IX. limestone is remarkable for containing large patches of nearly pure hematite; on microscopic examination the grey portions of it prove to be wholly made of fragments of *Entomostraca* and bone, curiously intermingled, and closely mixed up, with the atoms of hematite.

Details of Levenshulme Railway Cutting in Upper Coal Measures.

Depth. ft.	in.		Thickness. ft.	in.
		Lower Permian, or Collyhurst sandstone, coarse, loosely aggregated grit, with pebbles of quartz, Lydian stone, and Jasper		
15	6	Purple shales, brecciated with fragments of the same...	15	6
29	6	Ditto green patches, and stripes	14	0
40	6	Purple hard marls	11	0
66	6	Ditto, lighter, with plants (?)	26	0

FAULTS.

Depth. ft.	in.		Thickness. ft.	in.
		Dark hard purple marl, green partings ...	8	0
		Green sandstone, with plants (?)	4	0
84	6	Purple marls	6	0
		I. *Limestone* ... ... 0 6 to 0 8		
		Green shale... ... ... 0 0¾		
		Limestone 0 2½		
		Shale 0 0½	2	1¼
		Limestone (Spirorbis) 0 4		
		Shale 0 0½		
		Limestone (Spirorbis)... ... ... 0 7		
86	7¼	Green shale... ... ... 0 2		
		Red rubbly rock...	0	9
		Purple marls *(Spirorbis)*	4	9
		Greyish purple marls	8	9
		Purple and green marls	6	0
		Purple shale, with dark bands	5	0
		Hematite red marl	0	3
		Green marl...	0	3
112	5¼	*Bastard rough limestone* 0 4		
		Purple calcareous marl 0 8		
		Limestone, very irregular 0 10 to 1 2	2	11¼
		Yellow parting 0 0¼		
116	3	Limestone purple fracture... ... 0 8½		
		Brown marl and limonite	0	3
116	9	Green shale	0	3
		Limestone 1 1		
		Brown parting 0 1	2	7
118	9	*Limestone*, brecciated pink... ... 1 5		
		Dark yellow marl	0	3
		Purple shaley marl	0	1
		Limestone, nodular, irregular fracture, pure 0 4		
120	3	Sandy purple marl, loose nodules as base 0 10	1	2
120	9	Green marl with *Spirorbis*...	0	6
121	7	Soft purple marl	0	10
125	7	Hard purple and variegated marls, plants (?)	4	0
130	10	Purple shales, green partings	5	3

Depth. ft.	in.		Thickness. ft.	in.
	III.	*Limestone* 0 5		
		Marl 0 0¼		
		Limestone ... ... 0 5 to 0 7		
		Marl 0 0¼		
		Limestone 0 7		
		Yellow marl... ... ... 0 7	4	5½
		Purple „ 0 11		
		Bastard Limestone 0 6		
		Purple marl 0 2		
135	3½	*Bastard Limestone* 0 8		
138	9½	Variegated marl (hematite)	3	6
	IV.	*Limestone* ... ... 1 2 to 1 4		
		Green and purple shale 0 1¼		
		Limestone purple... ... ... 0 4½	2	9¾
		Purple marl... ... ... 0 3		
141	7¼	*Limestone* 0 9		
146	7¼	Purple shale, with cubical fractures	5	0
149	7¼	Brown „ „ „	3	0
153	7¼	Purple „ „ „	4	0
160	1¼	Crimson „ „ „	6	6
160	2¼	Limonite „ „ „	0	1
	V.	*Limestone* with ½″ of shale at 6″ and		
163	8¼	1′ 10″ from base	3	6
		Purple and green marls	7	6
		Hematite marl	0	10
		Brown marl...	2	0
		Purple and green marls	4	6
181	0¼	Purple marl	2	6
181	0¾	Green Marl...	0	0½
181	11¾	*Limestone* 0 10		
	F.	Ditto, with fish remains 0 1	0	11
		Shale 0 0½		
		Nodular Limestone 0 4		
		Green *calcareous* shale 0 5	2	8½
184	8¼	Purple marls 1 11		
	G.	*Limestone* (hematite blotches) ... 0 3½		
		Marl 0 0¼		
		Limestone, very rough surface ... 0 1¼	0	8¾
		Yellow marl... ... ... 0 1		
		Purple marl... ... ... 0 2		
185	5	Limestone 0 0¾		

Depth. ft.	in.		Thickness. ft.	in.
186	3	Reddish marls	0	10
		H. *Limestone* 0 8½		
		Bright green marl 0 2		
		Compact hematite marl 0 1		
		Earthy ironstone—olive brown ... 0 2½	2	0
		Purple marl... ... ... 0 3		
		Cal. nodules in yellow marl ... 0 6		
188	3	Purple marl... ... ... 0 1		
189	9	I. *Limestone*, very rough...	1	6
		Green marls... ... ... 0 2		
		Purple marl... ... ... 0 4		
		Green and red marls 1 0	3	6
193	3	Purple and grey marls 2 0		
		J. *Limestone* (Fish bed) 0 1		
193	8	Green marl 0 4	0	5
		Limestone 0 9		
		Limestone 1 3	3	10
197	6	*Limestone* 1 10		
198	6	Green marl	1	0
254	6	Red „	56	0
256	0	Mottled marl	1	6
256	10	*Limestone*, with hematite	0	10
258	10	Mottled marls	2	0
260	10	Purple „	2	0
261	5	Red hard shale	0	7
261	8	*Limestone nodules*	0	3
262	4	Light purple marl	0	8
263	3	Indurated green marl...	0	11
443	3	Purple marls	180	0(†)

The section here dips beneath Glacial Drift.

The Limestones occurring in the Upper Coal Measures of Western Britain, appear to have been first noticed by Mr. Francis Looney, F.G.S., in the key to Elias Hall's Geological Map, at Ardwick, near Manchester, who described, early in the century, fish remains from that horizon and from the Bradford Coalfields, but Professor Williamson was the first to fully describe them, in a memoir (*London and*

Edinburgh, Phil. Mag., 3rd Series, Vol. IX. p.p. 241–348. 1836) on the Limestones found in the vicinity of Manchester, and at the first meeting of the British Association in the county of Lancaster, held at Liverpool in September, 1837 (*Report Brit. Assoc.*, 1837, p. 81), a paper was read "On the Coal Measures of West Lancashire," by Mr. (now Professor) W. C. Williamson, F.R.S., in which he describes the Fossil Fish of the Lancashire Coalfield, and refers to those occurring in the Ardwick Limestones, the Bradford Coalfield, and the Black and White Mine at Peel, *Palæoniscus*, *Holoptychius*, and other genera being described. It is worthy of note, that the late Sir Philip Egerton, F.R.S., and Dr. Dalton, F.R.S., were Vice-Presidents of this meeting. In 1837, Sir Roderick Murchison made a careful examination of the Shropshire Upper Coal Measures Limestone, which he found charged there and in Manchester with a shell he named *Spirorbis* (*Microchonchus*) *Carbonaria*, which has since proved to be an annelid. In the Shrewsbury and Coalbrook Dale Coalfields he describes the limestone as varying from 2 to 9 feet, and occurring associated with mottled clays, greenish grits, and a calcareous breccia, resembling volcanic ashes.

In 1839, Mr. Binney adopted Elias Hall's term of "the Manchester Coalfield," for the Upper Coal Measures, and described the fishes of what he called the Coal Measures freshwater limestones of Ardwick and Uffington, and Leebotwood, in Shropshire, and refers to Sir Roderick Murchison's discovery of the *Spirorbis*, the *Microconchus Carbonaria* in these beds; and describes his own investigation of the fish remains occurring in the limestones, which he considered belong to the genera:—*Ctenoptychius*, *Megalichthys*, *Diplopterus*, *Palæoniscus*, *Platysomus*, *Diplodus*, and large long rays, resembling those found at Burdie House in Scotland. The thickness of these strata (River Medlock), he states, "from the turn in the river to the Beswick Toll

Bar, is about 150 yards (450 feet). From the last-named place to the Openshaw Coal, the highest Mine that has been worked in the district, must be near 100 yards. The Bradford and Clayton Mines next succeed here, and seven seams have been worked."

Mr. Binney then goes on to describe the so-called boundary fault of the Coalfield, bringing in the New Red Sandstone, and adduces evidence to show that the latter abuts against an old short line of the former, and is not a fault in the geological acceptance of the term. It is of interest to note that the Permians at Levenshulme lie naturally on the Coal Measures, in the manner suggested by Mr. Binney, east of Manchester.

Mr. Edward (now Dr.) Hull, F.R.S., in 1864, gave a detailed description of the Manchester Upper Coal Measures, in the Geological Survey Memoir, "On the country around Oldham." He states, "In no other part of Britain have calcareous beds been so strongly developed in the upper part of the Carboniferous rocks. In most other districts where they are represented, a single band of limestone, a few inches in thickness, is all that occurs. Here, however, there are at least six beds, with an aggregate thickness of about 15 feet of limestone; but it is to be recollected that this is not the entire amount that has been formed, for as the Coal Measures dip unconformably under the Permian Sandstone, it is highly probable that still higher bands of limestone lie concealed under the Triassic and Permian rocks of Manchester."

Professor Hull describes the Ardwick Limestones as "grey, white, or reddish," as "unevenly bedded, and having often the appearance of breccia cemented by carbonate of lime," all of which are familiar characteristics of the Limestones that have passed under your review from Levenshulme, where his forecast as to higher beds being discovered has been amply verified.

He estimates the vertical distance from the lower limestone at Ardwick to the Openshaw coal, in the Bradford and Clayton coal series, as 200 yards, which consists of the following :—

	ft.	in.		ft.	in.
Openshaw Mine	2	6	to	3	0
Measures ... ... about				135	0
Charlotte Mine	1	6	to	2	0
Measures				210	0
Three-quarter Mine				1	7
Measures				15	0
Four Feet Mine (Main Coal) = *Worsley 4 Feet*				3	10

At Ardwick, the section recorded by Professor Hull, F.R.S., is as follows :—

ft.	in.		ft.	in.
36	0	Boulder clay and sand	36	0
120	0	Red sandy loam, shale and clay	84	0
123	3	*Limestone yard mine*	3	3
128	0	Brown shaley clay	4	9
130	0	*Limestone Half-yard mine*	2	0
148	0	Reddish shale and clay	18	0
152	0	Blue clay	4	0
176	0	Sandstone	24	0
194	6	Shale, with joints	18	6
195	0	Black band *ironstone* (*Anthracomya Phillipsi*)	0	6
196	0	Coal and bass	1	6
206	0	Strong clay	9	6
212	6	*Limestone, Great Mine*	6	6

At a still lower level occurred a Limestone 18 in. in thickness.

Since the publication of the *Survey Memoir*, a very important boring has been carried out in search of coal, in Openshaw, attention to which was drawn, whilst it was in progress, by the late Mr. Binney, and numerous fossils were collected from the Permian marls, and ferns from the Coal Measure shales, and a careful section was made, the results of which below the Permian marls here follow. The upper beds will be described with

the Permians of Levenshulme in the third and concluding part of this communication.

Clayton Vale Boring, Openshaw, near canal.

Depth from the Surface. ft.	in.	Strata.	Thickness. ft.	in.
1042	0	Dark-grey shale	5	0
1058	0	„ „ gritty shale	16	0
1075	0	Purple shale	17	0
1080	0	Dark-grey shale, rather gritty	5	0
1080	6	Grey sandstone	0	6
1084	0	Purple shale	3	6
1088	0	Dark-grey and purple shale	4	0
1101	0	„ „ sandstone	13	0
1147	0	Purple shale, very dark purple	46	6
1149	11	*Grey earthy limestone*	2	4
1150	1	Grey shale	0	2
1177	2	Purple shale	27	1
1186	6	*Grey limestone*	9	4
1192	6	Purple shale, with green shale	6	0
1194	2	*Grey limestone*	1	8
1196	0	Grey and purple shale	1	10
1196	4	Purple shale	0	4
1199	0	*Brown limestone*	2	8
1201	8	Purple shale	1	8
1205	0	*Grey limestone*	4	4
1214	4	Purple shale	9	4
1219	4	Red shale and limestone breccia	5	0
1224	4	Variegated shale...	5	0
1224	10	*Limestone* breccia	0	6
1230	4	Red shale	5	6
1232	2	*Limestone*, earthy	1	10
1237	2	Variegated shaley clay	5	0
1237	8	Grey *limestone*	0	6
1238	2	Shale	0	6
1239	8	Grey *limestone*	1	6
1241	2	Purple shale	1	6
1241	11	*Limestone*	0	9
1242	2	Shale	0	3

Depth from the Surface. ft.	in.	Strata.	Thickness. ft.	in.
1243	8	Grey *limestone*	1	6
1248	2	Shale and clay	4	6
1259	5	Variegated purple shale	11	6
1265	2	Purple shale, lenticular *ironstone*	5	8
1266	2	Red sandstone, very fine	1	0
1277	6	Red and grey sandstone, very fine	11	4
1280	9	Purple shale	3	3
1281	6	*Calcareous* band, with *ironstone*...	0	9
1289	6	Sandstone and shale	8	0
1299	0	Red and grey sandstone *(Neuropteris)* ...	9	6
1300	0	Red shale	1	0

The vertical thickness of the Coal Measures here penetrated amount to 263 feet, of which about 34 feet consist of limestone, limestone breccia, and ironstone.

At Messrs. Deakin's (now Manchester Brewery Company) well at Ardwick, the Upper Coal Measures occurred at a depth of 483 feet from the surface, thus :—

489	2	Hard red marl, with limestone and hematite bands	6	2
489	9	Red and grey shale	0	7

At Messrs. Fryers and Co.'s Sugar Works the Upper Coal Measures occurred at a depth of 420 feet, the section being :

546	0	Red and purple marls, with bands of *Spirorbis* limestone...	126	0

At Messrs. Worrall's Dye Works, Ordsall, near Salford, the Coal Measures were reached at a depth of 1,230 feet ; 6 feet 6 inches of hard grey rock, resting on red marl, was only proved, the total depth being 1,236 feet.

The Permians were not penetrated at Messrs. Grove and Whitnall's Brewery, Regent-road, at 666 feet from the surface, or at Messrs. Holt's Brewery, Cheetham Hill, at 526 feet.

At Mr. Wood's boring, in Medlock Vale, near Waterbourne, the base of the Permians was reached at a depth of 718 feet 10 inches, and 143 feet 7 inches of Coal Measures were proved beneath; no limestones occurred, the beds consisting of red, grey, and black sandstones, shales, marls, and fire-clays. These beds are probably below the Ardwick Limestones, and there appears to be little doubt that the Levenshulme Limestones are above those of Ardwick, though belonging to the same physical group. It may, hereafter, be convenient to describe them as the Ardwick and Levenshulme Limestones; these portions of the Upper Coal Measures obtaining their maximum development in England in the districts so named.

West of Manchester, the Upper Coal Measures have been proved at several points; our knowledge of them is largely due to the late Mr. Binney, but has been usefully supplemented by Professor Hull.

At Patricroft, under the Permian, occurred:—

	ft.	in.
Red and grey shales	10	0
Hematite band	2	0
Shales and sandstone	174	0
Slack Lane Coal	1	10
Shale and sandstone	1006	0
Worsley Four Feet Coal	4	0

The total depth was 1,324 ft. 3 in.

The ironstone was identified by Binney as that occurring at Beswick Lodge, just referred to, and he remarks "that both occur in shales containing the bivalve shell *Anthracomya Phillipsi*." [Named after Dr. Phillips, of Manchester, by Mr. (now Professor) Williamson, in 1836.]

This calcareous ironstone (22 to 26 per cent of metallic iron) has recently been identified by one of us in a boring for water at Monton, and it doubtless lies over a large area underlying the Manchester Ship Canal. It is worthy of

note that only 396 yards of measures intervened between it and Worsley Four Feet Coal, and that the Limestones Measures have been removed by denudation before the Permian era, and it appears highly probable that westwards this denudation has been even more extreme, and that workable coals are still nearer the surface; but still further westward the Upper Measures are again in force, the *Spirorbis* Limestone appearing at Whiston four feet in thickness. It is there overlaid by a purple sandstone.

The *Spirorbis* Limestone is present in nearly all the western Coalfields extending from the Abberley Hills to Ayrshire, a distance of 250 miles, with a mean width of 50 miles, so may be assumed to have been deposited over an area of not less than 12,500 square miles. In several districts there is evidence that before the deposition of these Upper Measures great denudation of the Middle and Lower Coal Measures had taken place, the Upper Coal Measures, in an extreme case, resting directly on the Old Red Sandstone. And there is also good evidence that extensive denudation took place before and during the Permian epoch, rocks of the latter resting on every member of the carboniferous series from the carboniferous limestones up to the highest Upper Coal Measures known, which occur in the Manchester district. Especially is this the case at Levenshulme, where the actual junction of the two series has been carefully studied by us, the base of the Permian containing well-rounded and travelled pebbles of jasper, limestone, Lydian stone, and vein quartz. The surface of the Coal Measures beneath is a clear, well-marked division of the most defined character, the uppermost beds consisting of indurated dark, greyish-purple marls, with numerous angular fragments of the same material, arranged in a manner that would be called a breccia were the material harder, and suggesting sub-aerial waste of an old

land surface, and that here no pre-Permian denudation of the carboniferous rocks has taken place.

Many tons weight of the limestone beds from Levenshulme have been conveyed to Brockhurst, where the various horizons have been kept carefully apart, and are available for future study; the effect of frost, and weathering, has disclosed many interesting fossil forms, which were not at first apparent. The fish and possibly reptilian remains are being studied by Mr. Wm. Davis, F.G.S., F.L.S., of Chevinedge, Halifax; the mollusca by Mr. Newton, F.G.S., F.L.S., of the Geological Survey; and Professor Rupert Jones, F.R.S., has undertaken the microscopic organisms.

Studying the fauna as a whole, it reproduces, in a remarkable degree, the forms occurring in the Burdie House Limestones, and points to a striking recurrence of conditions, the one occurring at the commencement of the Carboniferous Epoch, the other at its close. It is worthy of note that the first appearance is in the more northern area, just as coal seams and their attendant flora preceded the deposition of the Carboniferous Limestones in the South of Scotland; in the North of England they only appear in the millstone grits, while in the South of England the latter are called the Farewell Rocks, the coal seams only coming in the true Coal Measures overlying. It is of interest, also, to note, that in the Arctic regions the coal seams of the "Ursa Stage" are older than the Carboniferous Limestones, and are about equivalent to the Burdie House series.

The recurrence of these early conditions is most marked in the Ardwick and Levenshulme series, where many microscopic slides of the limestone are undistinguishable, in the character of the minute fauna, from the forms present in those from Burdie House.

It is a source of satisfaction to bring before the Society

a detailed description of these beds, the earliest description of which it fell to the lot of one* of us to lay before you in 1883, when the nature of the underlying deposits were then unknown. It was, however, pointed out that whatever age they might be, they were cut off to the east, by a downthrow fault bringing in the New Red Sandstone. The truth of this has since been well established by numerous borings in that direction.

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* W. Brockbank, F.G.S., "On the Levenshulme Limestone."—*Memoirs Man. Lit. and Phil. Soc.*, Third Series, Vol. VIII.

Ordinary Meeting, March 24th, 1891.

EDWARD SCHUNCK, Ph.D., F.R.S., F.C.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Mr. FARADAY exhibited a specimen of crystallised bismuth, presented to the Society's collection by Mr. GEORGE FREEMANTLE, of Manchester, and the thanks of the members were accorded to Mr. FREEMANTLE for his interesting gift.

Mr. WM. BROCKBANK, F.L.S., F.G.S., read the following "Supplementary Note on the *Annelida* and *Entomostraca* in the Levenshulme limestones":—

"On examining the microscopic sections of these limestones, many objects were seen which were not fully described, or named, in my paper of December 2nd, 1890. The *Entomostraca* cannot well be identified when thus seen, cut through by the section. All the published plates of the *Entomostraca* represent the exterior forms of the objects. Many similar fossils to those seen in the limestones have since been found in the shales and clays at Levenshulme which are interbedded with the limestones, and they probably represent the same varieties as those entombed in the solid rocks. A good many of these small objects, which are about the size of bird seeds, have been washed out of the shales and clays by Mr. Roeder and others, with infinite care and much trouble, and a collection of these tiny *Entomostraca* has been submitted to Prof. T. Rupert Jones and Mr. L. W. Kirby, whose description of the varieties has been published in the *Transactions* of the Manchester Geological Society for the present

session, together with an excellent plate, shewing the objects magnified about 30 diameters. They are all described as belonging to the genus *Carbonia*, and the number of species, six. Messrs. Jones and Kirby say the *Carbonia* are rarely found associated with truly marine fossils—but they swarmed in muddy waters of the coal period with fish, amphibia, *Anthracosia*, and shells of that family, the ubiquitous *Spirorbis Carbonarius*, and coal plants (ferns excepted), and are probably indicative of Estuarine habitats. The old name for these fossils was *Ostracoda*. It is interesting to have these illustrations, but they do not compare successfully with the beauty of the same objects when seen under the microscope, as preserved in the limestones, where every detail of the shell construction is beautifully shewn. The microscope sections exhibited to the Society have also been examined in London by Professor Jones, Mr. Newton, and others, who believe the *Entromostraca* therein to be the same as those submitted by Mr. Roeder. The various forms of *Annelida* seen in the limestone sections may be understood by comparing them with a plate published in the *Geol. Mag.* for 1880. That volume contains a series of Articles by R. Etheridge, Junr., on the British Carboniferous tubicular *Annelida*. There are several forms of *Spirorbis* described and shewn, two of which occur in the Levenshulme limestones. Mr. Etheridge says the living *Spirorbis* is a marine insect. The two varieties of *Spirorbis* which I believe to be represented in our limestones, are (1) *S. Pusillus* and (2) *S. Ambiguus*. *S. Pusillus* is stated by Mr. Etheridge to occur in the Ardwick Limestone, and to be the species described by Phillips, Binney, and Salter. The range of strata through which this tiny annelid existed is enormous as it was found by Dr. Hibbert, at Burdie House, in a limestone at the very base of the Coal Measures—as well as in our limestones at the uppermost portion. At least 10,000

feet of Coal Measures intervene between the Burdie House and the Ardwick Limestones, and we have practically the same *Spirorbis* in both. It is the simplest of all the species, the coil being open, lax, and imperfect. A great peculiarity of this form, noticed by many observers, was its power of burrowing, or making an impression on the surface of any object to which it became attached. It was also solitary in its habit, and is frequently found upon the fronds of fossil ferns. The other variety which occurs in our microscopic sections, *S. Ambiguus*, has a nautilus-like section when cut through the centre. Mr. Etheridge says *S. Ambiguus* appears in the marine limestones to take the place of the burrowing form *S. Pusillus*, which is so essentially characteristic of the brackish water deposits of the same epoch. In *S. Ambiguus* the tube is globose, dextral, whorls one to one and a half, but concealed by the last volution. This species is decidedly gregarious, living in small clusters. The form certainly appears in all the lower Levenshulme limestones where the mollusca and fish remains are present, and it is not seen in the uppermost limestones. In estuarine formations, where fresh water alternated with brackish and salt waters at certain periods, the varieties of *Spirorbis* may thus help us to judge whether the bed of limestones is of fresh water or marine origin. Many examples of *S. Ambiguus* are to be seen in the microscopic sections submitted to the Society. Another form of Annelid seen in our sections is the *Serpulites Carbonarius* tubes of thin shelly material from 1½ to 3 lines in width. It is distinguished from the *Serpula* by its narrow elongated form. Of the *Serpula* there are many examples, and they are generally attached to other objects. *Vermilia* are also very common, tiny tubes of wavy form, covering shells; such are to be seen on our sea coast at this time. There are also many tubular objects with annulations like tiny encrinital stems. These belong

to the genus *Ortona*, which was originally proposed for the Silurians. There is, however, *Ortona Carbonaria*, a tubicular annelid with small tube, slightly conical, straight, or slightly curved, with circular sections ornamented by sharp continuous undulations or rings, which agrees nearly with our objects. Lastly, we find in our sections tiny curved spine-like objects, which may be taken to belong to the sixth class of the annelids, viz., *Ditrupa*. Tubes, small, elongate, curved, plain, smooth, hollow, tapering gradually. This is the tiniest annelid of all, and it is now living on the coast of Madeira. It is found in the Scotch Coal Measures. It will be seen, therefore, that all these forms of annelids are characteristic of the Carboniferous Epoch. A correct knowledge of these tiny objects is of value, as it enables us to recognise an Upper Coal Measure limestone by a very simple microscopic test."

Mr. J. COSMO MELVILL, M.A., F.L.S., read a paper entitled "An Historical Account of the genus *Latirus* and its dependencies, with descriptions of eleven new species," and presented a catalogue of *Latirus* and *Peristernia*, embodying the results of his re-classification. A collection of the shells was exhibited.

A paper by Mr. W. W. H. GEE, B.Sc., F.C.S., and THOMAS EWAN, Ph.D., B.Sc., on "The Comparison of Thermometers," was read by the last-named gentleman, who was introduced by Mr. GEE.

On the Comparison of Thermometers. By Thos. Ewan, Ph.D., B.Sc., and W. W. Haldane Gee, B.Sc., F.C.S.

(*Received March 24th, 1891.*)

The experiments described in the following paper were undertaken with the object of finding a practical method for standardizing platinum resistance thermometers and comparing them with mercurial thermometers.

The platinum thermometer, as suggested by Siemens, has been improved by Callendar,* who found that, if the ratio

$$100\left(\frac{R_t - R_0}{R_{100} - R_0}\right),$$

be taken as 'temperature by platinum thermometer' $= pt$ [where R_t, R_0, and R_{100} are the resistances at $t°$, 0°, and 100° respectively], then the differences between the readings of an air thermometer and those of the platinum thermometer are represented by the equation

$$t - pt = \delta\left\{\left(\frac{t}{100}\right)^2 - \frac{t}{100}\right\}$$

For the specimen of platinum wire used by Callendar the constant δ was found to be 1·57. This formula agreed with the results within 1% through a range of 700 degrees.

Griffiths† has confirmed these results, and has shown that the δ formula represents the differences between the

* *Phil. Trans.* 1887. A.

† Brit. Ass., Leeds Meeting, 1890. (*Electrician*, Oct., 1890.)
Proc. Roy. Soc., June, 1890.
Callendar and Griffiths, *Proc. Roy. Soc.*, Dec., 1890.

readings of air thermometer and the platinum thermometer with even greater accuracy than Callendar had supposed.

Under these circumstances we thought it desirable to elaborate a method which would allow of the platinum thermometer being standardized and then used for comparison with mercury thermometers, and especially to find what degree of accuracy could be attained without the use of elaborate precautions or special apparatus.

To determine the fixed points on the scale of the platinum thermometer we immersed it in the vapour of water boiling under diminished pressure. The same apparatus served for the comparison with the mercury thermometer.

Regnault's tables of the pressures of aqueous vapour

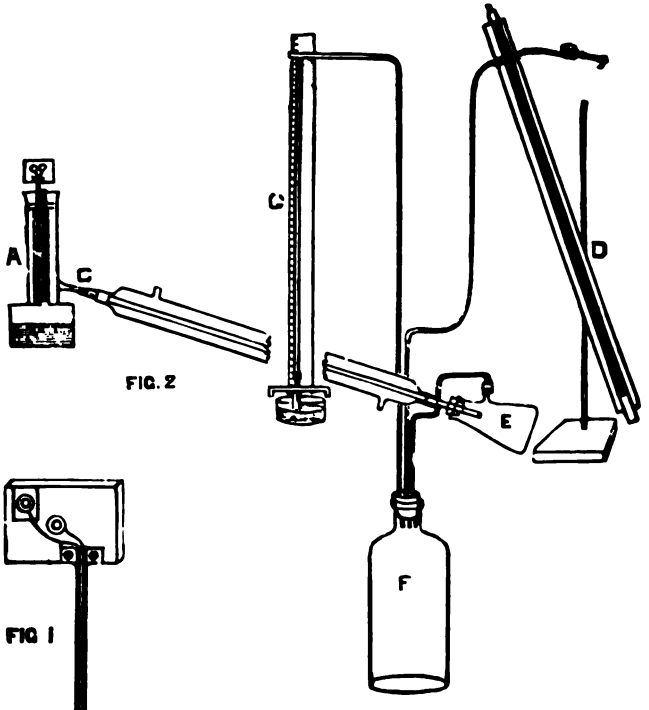

FIG. 2

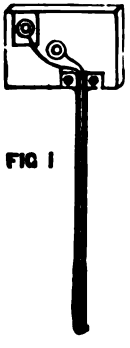

FIG 1

have already been used by Shaw* for measuring temperatures. He aspirated a known volume of air saturated with moisture at a temperature 't,' through tubes filled with pumice moistened with strong sulphuric acid. The increase in the weight of these tubes gave the data necessary for calculating t. This method is, however, only applicable to ordinary temperatures.

The platinum thermometer (Fig. 1.) which we used was made under the direction of Mr. E. H. Griffiths, by Mr. Thomas, of Cambridge. It consists of a platinum wire coiled on a roll of asbestos paper. The ends of this wire are soldered to thick copper leads, which communicate with binding screws. The coil is protected by a thin glass tube closed at the lower end. The copper leads are insulated by narrower glass tubes. The resistance of the coil at 0 was 10·637 ohm.

The mercurial thermometer used was one by Hicks, and was graduated in ½ degrees. The calibration of the stem gave the following corrections :—

Correction at	100°	+ ·38
,,	,, 90	+ ·32
,,	,, 80	+ ·27
,,	,, 70	+ ·22
,,	,, 60	+ ·15
,,	,, 50	+ ·14
,,	,, 40	+ ·12
,,	,, 30	+ ·08
,,	,, 20	+ ·06
,,	,, 10	+ ·03
,,	,, 0	+ 0·0

The measurements of the resistance were made by means of a post-office resistance box, by Elliot, and a sensitive galvanometer. The resistances were read directly on the box to ·01 ohm, and the numbers in the third decimal

* Cambridge, *Phil. Trans.*, 1885.

place obtained by interpolation from the deflections of the galvanometer.

The resistance coils were of German silver, and were correct at 19°C. The temperature was taken by a thermometer (graduated in tenths of a degree) placed inside the box, but owing to the construction of the latter the thermometer could not be in actual contact with the coils, which introduces a considerable uncertainty into the correction for the temperature of the coils. Most of the irregularities in the measurements of temperature by platinum thermometer are probably due to this. The correction was applied by the formula

$$R_{19} = R_t[1 - 0{\cdot}0004433\ (19 - t)]$$

An error of 1° in taking the temperature of the coils may make an error of 0·2° in the temperature measured by platinum thermometer.

The platinum coil was connected with the resistance coils by thick leads, consisting of bundles of copper wires. Three or four Leclanché cells were used, and a commutator was included in the circuit.

After several unsuccessful attempts the apparatus shown in Fig. 2 for boiling water under diminished pressure was found to give satisfactory results.

It consists of a copper vessel A, such as is used for determining the boiling point of thermometers. The upper end is closed by an india-rubber stopper, through which two glass tubes pass. One of them terminates shortly below the stopper, and through it the stem of the platinum thermometer passes, the joint being closed air-tight by a piece of india-rubber tubing slipped over both tubes. The other is long enough to admit the mercurial thermometer, and is closed at the lower end, and filled with water covered by a layer of paraffin, or better, with mercury.

It is necessary to protect the mercury thermometer in this way, as the exposure of its bulb to the diminished pressure inside the apparatus may produce a very sensible error in its indications (*vide Guillaume Thermométrie de Précision.* Paris, 1889).

Regnault,* in his experiments on the Vapour Tension of steam, made use of a similar arrangement. Some experiments which he made on this point showed that the readings of the thermometer at 100° were the same whether it was directly exposed to the steam or not.

The steam issuing from the opening C is condensed by an ordinary Liebig's condenser. It is important that there should be no narrow tubes in this part of the apparatus, otherwise the pressure in the boiler may be higher than that indicated on the gauge.

The gauge (G) was of the simple barometer form, the tube being 12mm. internal diameter. The height of the mercury was read on a brass meter scale, placed behind the tube, by a telescope at a distance of about 6ft.

The pressure regulator D was of the form described by Nicol,† and Stadel and Schummann,‡ and was found to give satisfactory results. The pressure could be kept constant within 0·5mm. for half an hour at a time.

The pressure regulator, the gauge, and the receiver E, communicate with one another through the reservoir F, which consisted of a Winchester quart bottle standing in a large vessel full of water.

The first experiments were made with a glass boiling apparatus, but at temperatures below 100°, the indications of the thermometer were 0·1° to 0·2° too high. The boiling point of the platinum thermometer was found practically

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* (Mèm: de l'acad: t. 21.)

† Nicol. *Phil: Mag:* (5) xxiii. 389.

‡ Stadel and Schummann. *Zeitschrift f. Instrumenten Kunde* 391. 1882.

the same in both the glass and the copper apparatus. The difference at lower temperatures is probably due to the fact that water does not boil regularly in a glass vessel under diminished pressure. This irregular boiling gives rise to sudden alterations in the pressure, and to overheating of the steam.

In making the measurements of temperature by the platinum thermometer, the greatest error was (as has already been mentioned) in the correction for the temperature of the resistance box. To eliminate this as much as possible, we took readings of the resistance at 0° and 100° before each set of observations, and then kept the temperature of the coils as constant as possible, while the readings at intermediate temperatures were made.

In determining the zero point, the platinum thermometer was left in the ice for at least an hour, and the current only closed momentarily (the first swing of the galvanometer needle being read), in order to avoid heating the wire.

The current was also reversed in order to eliminate thermal effects. No correction was made for the resistance of the copper leads.

The zero point was found at different times.

Resistance at 0°.	*Mean.*	*Difference from Mean.*
10·6388	10·6372	+ ·0016
10·6401		+ ·0029
10·6343		− ·0030
10·6360		− ·0012

It is possible that the alteration in the resistance is due to slight strains in the wire, as the protecting glass tube was not rigidly attached to the wooden part of the thermometer.

The following are the determinations of the resistance at 100° in the order in which they were made, and it is curious that they increase and decrease regularly.

		Mean.	*Difference from mean.*
In glass apparatus.	14·3369	14·3212	+0·0157
	14·3230		+ ·0018
	14·3149		− ·0063
	14·3168		− ·0044
	14·3183		− ·0029
	14·3225		+ ·0013
		Mean.	
In copper apparatus.	14·3226	14·3202	+ ·0024
	14·3243		+ ·0041
	14·3209		+ ·0007
	14·3176		− ·0026
	14·3154		− ·0048

The ratio $\frac{R_{100}}{R_0}$ from the experiments in the glass apparatus is 1·3463, from those in the copper apparatus 1·3462. These numbers agree very closely with those obtained by Callendar (1·3464), and by Griffiths (1·3462).

The following numbers will serve to show the degree of accuracy which may be reached in measuring the temperature by platinum thermometer.

pt is Temperature by Platinum Thermometer.

R.T. is the boiling point of water according to Regnault, corresponding to the observed pressure.

Resistance.	*pt.*	*Pressure.*	*R.T.*	*Pt. Corr.*	*Diff.*
14·0414	92·40	573·73	92·33	92·30	+ ·03
13·8206	86·47	456·22	86·32	86·29	+ ·03
	R_{100} = 14·3209		R_0 = 10·6395		
14·1371	95·15	636·79	95·13	95·08	+ ·05
13·8168	86·45	454·98	86·25	86·26	− ·01
13·5516	79·24	339·75	78·92	78·98	− ·06
	R_{100} = 14·3154		R_0 = 10·6360		
14·0934	93·78	603·71	93·69	93·68	+ ·01
14·1178	94·40	619·03	94·36	94·32	+ ·04
13·8947	88·34	490·59	88·20	88·18	+ ·02
13·6523	81·76	376·38	81·46	81·53	− ·07
	R_{100} = 14·3243		R_0 = 10·6395		

The column *Pt. Corr.* contains the readings of the platinum thermometer reduced to air thermometer degrees by Callendar's formula, viz :—

$$t - pt = \delta\left\{\left(\frac{t}{100}\right)^2 - \frac{t}{100}\right\}$$

where δ was 1·57, agreeing with the number found by Callendar and Griffiths.

The following table contains the results of a comparison between the readings of (*a*) the Platinum Thermometer (*b*) the Mercurial Thermometer, (*c*) the number from Regnault's Tables (calculated by Broch, *Trav. Bur. Poids et Més. I.*)

a.	*b.*	*c.*	*c*—*b.*	*c*—*a.*	*Error by airect calibration.*
	100·17	100·55	+ ·38		+ ·38
	100·00	100·398	+ ·398		
95·08	94·83	95·13	+ ·30	+ ·25	+ ·35
92·30	92·00	92·33	+ ·33	+ ·30	+ ·33
86·26	86·00	86·25	+ ·25	+ ·26	+ ·30
78·98	78·67	78·92	+ ·25	+ ·31	+ ·26

These numbers show that as far as the experiments have been carried the method is accurate within 0°·1.

If a greater degree of accuracy be desired, the coils may be kept at a constant temperature by means of a thermostat, which is the method used by Griffiths, or the measurements may be made with a slide meter bridge, the comparison being made with reference to coils immersed in water. It would also be advantageous to increase the resistance of the thermometer.

An Historical Account of the genus Latirus (Montfort) and its dependencies, with descriptions of Eleven new species, and a Catalogue of Latirus and Peristernia. By James Cosmo Melvil, M.A., F.L.S.

(Received March 24th, 1891.)

(I.) *Early History and Classification.*—When Linnæus first drew distinctions between the various marine Gasteropods, and assigned them to families and genera, he, and his immediate successors, until, indeed, the time of Cuvier and Lamarck, relied entirely upon the form of the shell alone, and usually took some one prevailing characteristic, such as a straight prolonged canal for instance, or a rounded mouth, however different in other respects the shells were from each other, dismissing their inhabitants in one terse sentence, "*Animal a Limax.*" Manifestly, by this rule, certain ranges of molluscs, the salient characters of which were not discernible without considerable study, especially of the animal, fell together into a heterogeneous "olla podrida," from which it has taken much time and patience for subsequent authors to extricate them.

Accordingly, it is not surprising to find, under the Linnean system, the few types then known of the genera we are about to discuss found in *Murex* (L.), in company with what are now considered *Murex* proper, *Ranella*, *Triton*, *Purpura* (pars), *Phos*, *Struthiolaria*, *Pleurotoma*, *Fusus*, *Neptunea*, *Pyrula*, *Ficulidæ*, *Hemifusus*, *Mangilia*, and *Cerithidæ*. They are placed in the ninth of the twelve divisions by the late writers on the Linnean system (*e.g.*, Mawe, 1823), in which the subdivision into two families is recommended, the first, consisting of shells turreted, outer

lip having a notch at the summit, *i.e.*, *Pleurotoma*; the second, with the column plaited, *Latirus* (Montf.) and *Fasciolaria* (Lam.). But, in justice to those who came before Lamarck, it must be recorded that Linnæus had placed in the genus *Voluta*, as opposed to *Murex*, the true *Turbinellidæ*, those large ponderous Molluscs with conspicuous twisted columella, and with lingual dentition very different from the *Latiri* and *Fasciolaridæ*. It was Lamarck, who in 1799, founded the genus *Turbinella*, and took the first false step in uniting shells which had so few characters in common, save the columellar plaits.

Denys de Montfort,* indeed, in 1810, differentiated the genus *Latirus*, not, however, on account of the true distinctions as now understood, but simply because of the infundibuliform umbilicus, which occurs more or less in many of the species, and the extent and depth of which varies exceedingly in specimens of the same kind.

I quote his original description (Conch., System II., pp. 531 sqq.):—

"Coquille libre, univalve, à spire turriculée ou fusiforme, bouche allongée, columelle avec impression de plis, tranchante vers l'ombilie, lèvre exterieur tranchante, base canaliculée, ombiliquée.

"Espéce servante de type au genre:—

"Le Latire orange.

"*L. aurantiacus* = *Murex filosus* (Lamk.)." *c.f.* Mart.: 4. t. 140., fig. 1308, 1309 et. t. 141., f. 1314—1316.

* Many genera of Denys de Montfort, prepared in his *Conchyliologie Systématique*, 1810, often upon insufficient grounds, have notwithstanding, survived to the present day, we signalize such well-known names as *Typhis*, *Trophon*, *Triton*, *Phos*, *Cylinder*, *and Hermes (two subgenera of Conus)* *Calpurnus*, *Pyrazus*, *Lanistes*, *Clithon*, *Clanculus*, *Helcion*, *Scaphander*, *Atys*, *Zonites*, *Gibbus*, *Melampus*, and *Cyclophorus*. An interesting note by Dr. J. E. Gray, F.R.S. in *Ann. and Mag. of N. Hist.*, 1869, p. 319, touching on the melancholy end of de Montfort, neglected and in most abject poverty, and also of the reduction in circumstances of the great Lamarck in his latter days, is worth perusal.

A most deplorable figure of the *M. filosus* is added, which only a reference to Martyn's plates can construe into possessing the slightest resemblance to the shell now termed *Latirus gibbulus* (Gmelin), this name (Syst., Nat. 1790) having priority over Lamarck's.

Taking this, however, as the type, we find associated with it a more or less attractive assemblage of Mollusca, one indeed, that it is marvellous has not received more due attention, for many of the members of it are singularly beautiful, both in structure, colour, and variety of form.

(II.) *General characteristics.*—The *Latiri* proper are mostly shells of a somewhat massive build, fusiform, whorls turreted, six to eight whorled, usually longitudinally ribbed or noduled, often smooth (*L. nodatus*) but more frequently transversely sulcated, filleted, or striated, canal very short (*e.g. Rousi, brevicaudatus, spadiceus, prismaticus*), or produced and deeply umbilicated (*infundibulum*), very long and fusoid (*lancea*) mouth sub-triangular, canal short, (*ceratus*) inner lip more or less with a tooth-like projection (*cingulatus* and *leucozonalis*). The interior in some cases is finely coloured, with pale violet or pink (*nodatus*). This is more frequent, however, in the *Peristerniinæ*, (*e.g. Nassatula, violacea*, whilst the mouth is yellow in the *striata* and *crocea* sections. The *Peristerniinæ* are more like *Nassæ* in outward appearance, with their short, sometimes slightly recurved beaks, while the *Latiri*, to sum up, often assimilate species of the genera *Fasciolaria, Fusus, Mitra, Monoceros, Columbella* and *Murex*.

The *plaiting of the columella* occurs as a strong family distinction, not only in this, but in several other leading families of Prosobranchiate gasteropods: *e.g., Mitra, Marginella, Cancellaria, Voluta, Turbinella* (*Mazza and Vasum*, Bolten), also, *internally*, in most of the *Columbellidæ*, and to some extent in the *Cerithidæ*.

The order *Fasciolariinæ*, as at present understood, embraces, altogether, species which possess these plaits, excepting the *Fusi veri*, *Clavella*, *Taron*, and *Buccinofusus*, genera, at the present day, associated with Fasciolaria in consequence of the similarity of dentition. Of this we shall speak shortly, as also of the animal. The *Opercula* are similar throughout, being horny, oblique, with nucleus apical.

To return to the plaiting of the columella, *Latirus Syracusanus* (L.), *Peristernia Brazieri* (Angas) and one or two others do not possess them, so far as is discernible; nor *Peristernia nassoides* (Reeve) a species abnormal in many ways. Owing, however, to a considerable amount of deposit of enamel on the columellar side of the labrum, it is probable the plaits get covered over and so obliterated, especially just at the orifice. This is certainly the case with the type of the genus *L. gibbulus* (Gmel.).

Reeve* well remarks on the *oblique* tendency of these plaits in the true *Fasciolariinæ* (*e.g.*, *F. trapezium*, *salmo*), also noticeable, but to a lesser extent, in the *Latiri* and *Peristerniinæ*, this compared with the straighter, more prominent convolutions of the true *Turbinellidæ*.

(III.) *Existing Monographs of the genera.*—These genera have been monographed by Kiener, Reeve, and Kobelt in *Küster's Conchylien-Cabinet*, the latter being the most perfect in arrangement of the three; Lovell Reeve, for instance, having taken the whole group in Vol. IV. *Conch. Icon.*, 1847, under the name *Turbinella* (Lam.) includes not only *T. pyrum* and its allies, as was natural at the time of writing, but also so distinct a form as *Cuma tectum* (Gray)! His figures were produced with rare fidelity and unsurpassed execution by the late Mr. Sowerby, and many species were then described by Mr. Reeve for the first time.

* *Conch., Icon.* Vol. IV. *Turbinella*, prefatory remarks.

In 1881 the late Mr. George W. Tryon, junr., treated of the genera in Vol III. of his *Manual of Conchology*, adopting Kobelt's treatise as the basis of his work; but in many ways drawing his own conclusions. To this I will refer later, in a separate paragraph.

IV. *Derivation of Name.*—LATIRUS.—"Le Latire," as de Montfort himself, the author, calls it, has been spelt (by P. P. Carpenter, for instance), Lathirus or Lathyrus—on the assumption that it was derived from λάθυρος, a pea, the brown shells perhaps suggesting a faint likeness to a ripe pod. A new solution has proposed itself to me, which I mention with all reserve, "lateritius," of or belonging to a brick, from the warm, sundried brick colour of some species, especially the type, *L. Gibbulus** (Gmelin).

PERISTERNIA is evidently derived from περί στέρνος, in allusion to the banding round the whorls, the same idea being intended in the names *Fasciolaria* and *Leucozonia*.

(V.) *Fossil Forms.*—Only twenty or thirty fossil forms of this genera are known to Woodward: first making their appearance in the chalk, and, more abundantly, in the Tertiary Deposits of some parts of the world. A great many have been recently described by Prof. Ralph Tate, in his Treatise on the Gasteropods of the older Tertiary of Australia†; and likewise by Von Kænen.‡ According to Fischer, all the various forms of the genus, as at present known, in the recent state, have their fossil analogues.—Doubtless many species at present called *Fusus*, *Murex*, or *Fasciolaria*, *cf. F uniplicata* from the Eocene (Germany),

* It is curious that in all the editions of Woodward's Manual, this species, figured rightly as the representative of the genus, should invariably be misspelt *Gilbulus*, both in the letter-press and plate-reference. Errata seldom run through several editions without being detected.

† *Trans. Royal Soc. Australia X.*, pp. 91—176, with 15 plates, 1889.

‡ *Das Nord Deutschen, Unter Oligocän, u. Seine Mollusken Fauna*, 1889.

Fusus antiquus. Eocene, Barton, belong properly to *Latirus*, and a further revision of these is much needed.

VI. *Further Historical Account: Classification, Dentition, &c.*—We have said that de Montfort's reasons for describing his new genus, *Latirus*, were inadequate, as he simply relied upon the presence of an umbilicus, as opposed to the true *Turbinellidæ*.

In his type (*L. gibbulus*) the infundibuliform umbilicus varies greatly. I have seven specimens, and in none is there much sign of columellar plaits, yet, as I have lately remarked, there can be no doubt as to this being an admirable type for a genus. The specimen has an umbilicus 15 mm. wide, whilst two are nearly closed. This shell is conspicuous for its ponderosity, bright warm chestnut colour, smooth with transverse lines running ribbon fashion across in pairs.

The same variation in the depth of the umbilicus may be found in *L. nodatus*, *infundibulum*, etc.; small wonder, then, that Dr. G. P. Deshayes, writing in the *Dict. Univ. d'Historie Naturelle*, *Tom.* VII., characterized the genus thus:—

"*Latirus*—Genre *inutile* établi par Montfort, dans sa *Conchyliologie Systématique*, pour le Fusus, *dont le columelle est ombiliquee*."

But, though in this sense useless, in other ways it has become one of the most abiding genera; for when the characters of the animal, and especially the Operculum and Odontophore, began to be studied and revealed, it was found necessary to remove these molluscs entirely away from the *Muricidæ* and *Turbinellidæ* proper: and place them in a family, proposed to be called *Fasciolariinæ* for their reception with the genus *Fasciolaria* (Lam).

And, after Dr. J. E. Gray had still further separated the *Leucozoniæ* in 1847, and Mörch the *Peristerniinæ* in 1852, it was left for Messrs. H. and A. Adams (*Gen. of Recent*

Mollusca) to tabulate the genera, with a more minute description of the dentition than had been previously given.

I think it well to quote their differentiation :—

FAM. FASCIOLARIIN.E.

Teeth on lingual membrane in three series (1.1.1.), the central recurved, toothed at the tip, the lateral not versatile; lateral teeth very broad, linear, with many equal teeth, central tooth narrow, small. *Mantle* enclosed, with a straight siphon. The *operculum* ovate acute, nucleus apical. *Shell* fusiform, aperture with a straight canal in front, and with plaits on the fore part of the pillar.

Genus FASCIOLARIA (Lamarck).

Shell fusiform, spire acuminated; aperture oval, elongated, as long as the spire; siphonal canal straight, columella smooth, with a few oblique plaits at the fore part, outer lip internally crenate.

•23 sp., nearly all of large size. *F. gigantea* (Kien.) being the largest Gasteropod known, reaching sometimes over two feet in length.

[Genus BUSYCON (Bolten). *Fulgur* (Montfort).
8 species. Removed to *Turbinellidæ*, as now revised].
c.f. Fischer Man. Con. p. 20.

Genus TUDICLA (Bolten).
3 species. Removed to *Turbinellidæ*].
c.f. Fischer ut suprà.

Genus LATIRUS (Montfort).

Shell turreted, fusiform, umbilicated; spire produced, whorls nodulous; aperture oval-oblong, outer lip thin, crenulated; columella straight, with two or three small oblique plaits in front.

• Many were synonyms. *Fasciolaria* at the present day is computed to contain 17 to 18 sp. only.

Subgenus PLICATELLA (Swainson).

Spire moderate, whorls angular, concavely depressed round the upper part.

* 31 sp. *Latirus*. 6 sp. *Plicatella*.

Genus PERISTERNIA Mörch.

Shell subturreted, not umbilicated; whorls longitudinally ribbed; aperture oval, canal moderate and recurved; outer lip thin and crenulated; columella with one or two slight plaits anteriorly.

21 sp.:—

Genus LEUCOZONIA (Gray).

Shell oval, subglobose; spire moderate; aperture oblong; canal short; columella sub-flexuous, with small oblique, unequal plaits; outer lip subacute, with a tooth or tubercle at the fore part.

15 sp. (including *Lagena*, Schum: in which the species are smooth).

Genus FASTIGIELLA (Reeve).

1 sp. now removed to *Cerithidæ*.

The old genus *Turbinella*, with *Cynodonta* (Schum) *Vasum* (Bolt.), being separated owing to the completely different dentition, the lateral teeth possessing one single large denticle only.

As recently as 1865, Mr. Crosse (*Journ. Conch.* XIII., p. 317, pl. 14, f. 1) in describing one of the species, mentions, "This shell has the general appearance of *Latirus* (Montf.), but no umbilicus, consequently it shows that the separation of *Latirus* from the other *Turbinellidæ* is not natural." I take it Mr. Crosse meant here, *Leucozonia*, *Peristernia*, and *Fasciolaria*, speaking of the order by its old name.

About the same time Dr. Troschel, of Bonn, examined and reported upon the radulæ of these four genera (*Gebiss*

* Many of these are mere synonyms.

der Schneck II., pp. 60—66, pl. 5, figs. 12—20, pl. 6, figs. 1—3), confirming the opinion that they all had three plates in each series, the lateral being transversely elongated and many cuspidate, the middle tooth square with three to five cusps. He placed *Fusus Syracusanus* (L.) an inhabitant of the Mediterranean, since it possessed the identical dentition of the *Latiri* but not the columellar plaits, in a new genus *Aptyxis* (ἄπτυξ), which, perhaps, it would be convenient to retain, at all events as a section, at present—although in the accompanying catalogue I have merged it altogether in *Latirus*.

In the year 1867, Stimpson removed *Peristernia* from the *Latiridæ* for the obscure reason that one specimen (not named) did not agree with the lingual dentition, but more resembled *Buccinidæ*. Probably this species has been long since ousted from the genus—(v. *Am. J. Conch.*, i. p. 57. sqq.).

In 1869 Prof. E. von Martens proposed to unite the whole series under one name *Fasciolaria* (*Nachr. Mal. Ges.* *I.* p. 190).

The same year Dr. John Denis Macdonald, F.R.S. (*Ann. and Mag. of N. Hist.*, Vol. III., sec. iv., p. 113), in a dissertation upon the dental plates and teeth of Proboscidiferous Gasteropods, remarks: "Being well aware of the existence of certain fusiform species having neither plaits nor folds upon the columella of the shell, but with lateral combs in the odontophore, I conclude that these would form, with *Cyrtulus* (Hinds), a well-marked family."

• • • • •

"*Fasciolaria* and *Mitra* form the types of two distinct families, the former with its lengthy ribbon and narrow median series, differing remarkably from the latter, which is short and broad."

The Revd. R. Boog Watson, F.R.S.E., in 1873 (*P. Z. S.* p.p. 363, 364), established a genus *Chascax*, founded on a

dredged specimen of *Latirus armatus* (Ad.) with abnormally large infundibuliform umbilicus. It has subsequently (*Rep. Voy. "Challenger" Gasterop.* p. 243) been abandoned by him, and relegated to a synonym. I have examined the original shell in the Brit. Mus. which is much corroded by external growths (nullipores, &c.), and perforated by annelids, and there can be no doubt as to its identity, and, considering how, as I have already remarked, the infundibuliform character varies in typical *Latiri*, I could hardly continue the use of the *varietal* name *Maderensis*, for this specimen. I may add that, in treating of these shells as dredged by the "Challenger" Expedition, the six species found, three *Fasciolaria* proper (one being *F. rutila*, Watson n. sp.), and three *Latiri*, are all named as belonging to Lamarck's genus *Fasciolaria*.

As already noticed, *Tudicla spirillus* (L.) had been originally included by Messrs. H. and A. Adams in *Fasciolariinæ*, but subsequently expunged owing to the dentition, and removed to *Turbinellidæ*. In *P.Z.S.*, 1874, p. 582, pl. lxix, fig. 2, Mr. Henry Adams attempted to defend his actions, especially laying stress upon the *Latiroid operculum*, but there can be no doubt that this genus is better located where it is.

It is different with *Cyrtulus* (Hinds), *Clavella* (Swainson), the latter name having priority of eight years. Judging from Dr. Macdonald's sketch of the dentition, in the article lately referred to, the fine comb-like laterals, and the tricuspidate central tooth, shew great kinship with *Fasciolaria;* and I note that M. Paul Fischer has in his invaluable *Manual* (1887), p. 616, placed it in this family, also including the *Colus* Section of Fusus, the dentition of which, as proved by Schako, firstly, in 1874, was found to agree in all its details with the *Fasciolariæ*, *F. inconstans* (Lischke), from Japan being the original species experimented upon. This arrangement is also now confirmed. About the

same time the *Ptychatracti* type:—*P. ligatus*(Mighels), *Fusus olim*, were moved by Troschel to the *Turbinellidæ*, in company with *Meyeria* (Dkr.) It is to this latter genus that the *Latirus albus* (Jeffreys) belongs, known only to us by the figure in "Depths of the Sea," by Wyville Thomson, from the Shetland Isles. The shell is apparently of *Latirus* form, and the plicæ on the columella are present. It is similar to *Peristernia scabrosa* (Reeve), with few longitudinal ribs. Shell of thin substance, but the dentition proves its alliance with the *Melongenæ*.

In 1878, *Fusus Berniciensis*(King), under the generic name of *Boreofusus* (G. O. Sars.) was proved to have the identical lingual dentition as *Latirus*, and though in the form of its shell approximating more nearly the *Neptunea*, with which it had been formerly associated, must in future occupy a place in this family. In this shell there are no plicæ to the columella, the form is ventricosely fusiform, pale pink, with brown epidermis more or less omnipresent, lightly concentrically ridged, every third ridge being more prominent, whorls somewhat effuse, canal slightly inclined, mouth ovate—a rare inhabitant of the North of England and Norwegian Seas. For a full description *vide Sars. Moll. Arct. Norweg.* p. 278, pl. xiv., fig. 2. Plate of *radula*, pl. x, fig. 26, and also *vide* Jeffreys.

The Rev. A. H. Cooke has just informed me that *Fasciolaria lignaria* (L.) = *Tarentina* (Gmel.) is more a *Latirus* than a *Fasciolaria* by its dentition. I had thought that, perhaps, the whole might be merged in *Fasciolaria*, as every gradation, between the large *F. gigantea* (Kien.), which measures sometimes, as already noticed, over two feet in length, to the small *Peristernia* of 10 mm. may be traced, but I am assured by Mr. Cooke that Mr. Gwatkin and he have studied the radulæ of many members of this group, and that not only do all the *Fasciolariæ* (with the exception of *F. lignaria*) retain the self-same characteristics, but the

Latirus are distinct from *Peristernia* in many particulars. Mr. Cooke, to whom I am much indebted, has lent me some very beautiful magnified photographs of the dentition of two species—*Fasciolaria trapezium* (Lam.) and *Latirus ceratus* (Wood). The dentition appears to vary as follows between the three genera :—

Fasciolaria (Lam.).	*Latirus** (Mtft.).	*Peristernia* (Mörch).
Central tooth tricuspidate, close together.	Central tooth tricuspidate.	Central tooth tricuspidate.
Lateral denticles, about 21 in number, long comb-like, equal length to base.	Lateral denticles about 10, broader at base, not so long as in *Fasciolaria*.	Lateral denticles irregular in size, about 8 large teeth, 5 small ones.

Mr. Cooke considers the dentition sufficiently distinct in *Peristernia* to keep that genus distinct from *Latirus*; but he has examined only four species of the genus, and it is very difficult to draw a hard and fast line, unless the odontophore of each is known and examined.

A small shell, *Taron dubius* (Hutton), from New Zealand, of which the Rev. A. H. Cooke very kindly forwarded me specimens, has been discovered by the dentition to belong to the *Latiridæ*. The shell is not unlike a small *Cominella*, fusiform, with short canal, columella smooth, lip simple, ornamented with transverse ribs, often semi-nodulous. Length 15 m. Breadth 7 m.

Apart from the lingual riband, the general aspect of the *Animal* of *Latirus* and *Peristernia* resembles the *Muricidæ*. The head is somewhat broader, eyes less protuberant, foot rather shorter than in typical *Murex*. The operculum is distinct, all the *Fasciolariinæ* possessing unguiform opercula, with the nucleus apical. When on the coral reefs of the Gulf of Mexico, in 1872, where I noticed *L. cingulifera*

* With *Aptyxis* (Troschel), *Taron* (Hutton), *Berrefusus* (Sars).

(Lam.) var. *Knorrii* (Desh.) the animal was dark red, of the colour of raw beef, and I believe all the animals of this genus that have been examined, are of that appearance. So far as I recollect, however, *Fasciolaria distans* (Lam.), which I found at Charleston, So. Carolina, commonly, did not possess this peculiarity, but was of a grey mottled colour, as also *F. tulipa* (Lam.), and its transversely ribbed var. *Scheepmakeri* (Dh.) which I found commonly on the coral reefs in the south. Good representations of the animals of this family may be found in Adams *Gen. Recent Mollusca*, Vol. III., pl. xvi., f. 1. *Latirus* (*Fasciolaria*) *lignarius* (L.) copied from Chiagni Poli. *L. turritus* (Quoy and Gaimard) *Voy. Astrolabe Moll.*, pl. xxxv., fig. 14. *Peristernia nassatula*, original sketch by A. Adams. *Latirus* (*Leucozonia*) *smaragdulus* (Quoy and Gaimard) *ut supra* fig. 21.

Mr. Cooke writes that the following species have passed under the critical observation of himself and Mr. H. M. Gwatkin, of Cambridge, and conclusively proved to be *Latiri*, *Peristerniæ*, or *Fasciolariæ*, by their dentition.

- LATIRI.
  - *Latirus castaneus*
  - *ceratus*
  - *cingulatus*
  - *knorrii*
  - *lignarius*
  - *polygonus*
  - *rudis*
  - *smaragdulus*
  - *Syracusanus*
  - *Borsofusus Berniciensis*
  - *Taron dubius*
- PERISTERNIINÆ.
  - *Peristernia crocea*
  - *incarnata*
  - *nassatula*
  - *ustulata*
- FASCIOLARIINÆ.
  - *Fasciolaria filamentosa*
  - *trapesium*
  - *tulipa*

Many of these identifications have never as yet been published.

It is, naturally, almost impossible that during the lifetime of this generation, we can hope to obtain accurate knowledge of the dentition of all the species included in these

genera. The above, however, are some of the more leading, common, and conspicuous members of the various groups, and therefore a considerable substratum of knowledge is formed by this valuable aid, armed with which, he who ventures on framing a line of sequence may, with some measure of confidence, forge the links of connection here and there, and unite the whole array in a congruous chain.

I would therefore propose to group the members of this family *Fasciolariinæ* thus :—

I. *Fusus* (Lamarck). Types *F. colus* (L.), *F. inconstans* (Lischke).

II. *Clavella* (Swainson), *Cyrtulus* (Hinds). Types *C. serotina* (Hinds).

III. *Fasciolaria* (Lam.). Type *F. tulipa* (Lam.).
Subg. *Pleuroploca* (Fisch.). Type *F. trapezium* (Lam.).

IV. *Taron* (Hutton). Type *T. dubius* (Hutt.).

V. *Buccinofusus* (Conrad).
Boreofusus (Sars.). Type *B. Berniciensis* (King).

VI. *Latirus* (Montfort). Type *L. gibbulus* (Gmelin).
Syn. in part *Aptyxis* (Troschel).
Do. *Leucozonia* (Gray).

VII. *Peristernia* (Mörch). Type *P. nassatula* (Lam.).

It is with the four last genera we alone have to do at present: the *Fusi* proper and *Fasciolariæ*, whose dentition is almost identical, may form the subject of a future paper. In both these genera, the denticles of the laterals are larger and far more numerous than in the *Latiri*.

It will be noted that the old genus *Leucozonia* of Gray is dispensed with in this new arrangement. The shells seemed to fall naturally into their places, in the centre of the sequence. The presence of a labial tooth, which is of extreme prominence in *L. cingulatus* (Lam.) does not, to

my mind, raise the question of generic distinction on that score alone. In a more or less undeveloped state, signs of such a tooth appear on many shells. The shell is almost more noteworthy on account of its bold sculpture, squarrose aperture, and transverse thread-like marking on the whorls, and I revert to it more fully in another part of this paper.

The *Peristerniinæ* were separated from the *Latiri* by Mörch, principally on account of the want of umbilicus, moderate and narrowed canal, and slighter plications of the columella, but there are many species which, pending the working out of the dentition, must be doubtfully placed in either genus. *P. Caledonica* (Crosse) is an undoubted *Peristernia*, but I have a specimen with a decided umbilicus; *P. annulata* (Bolten), allied to *P. flavida* and *P. infracincta*, is, perhaps, better placed in *Latirus*, near *L. Syracusanus* (L.), and so on.

The species are nearly all small, and highly coloured, especially as regards their mouths and columella; and their form is more like the *Nassæ* or *Nassariæ* than is *Latirus*, which more assimilates members of the *Muricidæ*.

Indeed, I know several conchologists who are of opinion these two genera should be merged, and, as I have already observed, it is only on account of the irregularity in size of some of the lateral denticles, and especially in deference to Mr. Cooke and Mr. Gwatkin's strongly expressed opinion, that I have not done so at the present opportunity.

(VII.) *Iridescence of Epidermis in certain species.*—In three or four species the epidermis, when wetted or oiled, shows prismatic reflections. I do not know this peculiarity in any other genus, nor does it exist in many Latiri. It is most conspicuous in the still uncommon *L. prismaticus* of Martyn, who, under its old title, *Buccinum prismaticum*, figured it in his *Univ. Conch.*, Vol. II., p. 2. This work, begun in 1784, is more noteworthy on account of its

beautifully executed plates than its letterpress, and the representation of *L. prismaticus* leaves nothing to be desired, as it was taken from a very fine specimen. At the sale of Mr. G. F. Angas' collection, in 1870, I acquired a beautiful example, with operculum, which shows the dark cobalt to indigo reflections to perfection—and have three others, which shew it in greater or less degree. The epidermis removed, all chance of obtaining these radiant results vanishes. Mr. W. Harper Pease (*Proc. Zool. Soc.*, 1865, pp. 53—54) gives full details of the exact localities for the above (see Catalogue), and compares with it *L. gemmatus* (Reeve) [*L. peristernia*], *violaceus* (Reeve) and *gibbus* (Pease), the latter being then described for the first time. In his opinion the four are nearly allied, though differing somewhat in form, from the fact that this prismatic iridescence is present in the epidermis of each. As we have said, the reflections in the type species are of a deep azure blue, *L. violaceus* possesses gold and silvery shades of purple and green, *gemmatus** and *gibbus* a fainter and not very conspicuous radiance. This only, in every case, when the epidermis is wetted or oiled.

I have often noticed, in deep tidal pools round our coasts, and likewise in those of other countries, certain marine Algæ, appearing beautifully prismatic in the water, steel blue or sea-green being the predominant reflections, the effect of which vanishes, however, entirely and immediately they are withdrawn from their native element into the open air. Such are the British *Rhodymenia palmata* (Grev.) and, above all, *Nitophyllum laceratum*, (Grev.) *Chondrus crispus* (Lyngbye), and *Cystoseira ericoides* (Agardh). It is possible that the *Latirus prismaticus*, and the other species with iridescent epidermis, feed exclusively on Algæ possessing this peculiarity, and so a colour resemblance has been given

* While these pages were in the press, Mr. J. R. Hardy, of Owens College Museum, has shewn me a beautiful specimen of *L. gemmatus*, showing prismatic reflections almost equal to *L. prismaticus*, from the collection of Mr. Lovell Adams, of Penistone, nephew of Messrs. H. and A. Adams.

them for purposes of protection. This seems not an improbable theory.

(VIII.) *On Latirus cingulatus* (Lam.).—This extraordinary, though not infrequent species, is not so isolated as would at first sight appear. The solid angularity of its uncouth whorls, and great extension of the outer labial tooth, distinguish it at once. It was originally placed by Lamarck in his genus *Monoceros*, with certain Purpuroid shells which are, likewise, ornamented with a more or less conspicuous tooth. Finally, Dr. J. E. Gray made it the type of his genus *Leucozonia*, having discovered its true affinities. The columellar plaits are well developed ; the dentition is precisely that of *Latirus*. As to be noticed in the remarks concerning the sequence here adopted, I have transposed this shell, with the other *Leucozoniæ*, to *Latirus* proper : — there are signs of the labial tooth in several of the allied forms, and *Latirus amplustris*, though untoothed, has intimate affinity in other ways with *cingulatus*.

The species is littoral, living on rocky coasts of Western and Lower California, Mexico, to Panama, the Rev. P. P. Carpenter, Prof. C. B. Adams, and other collectors having noticed it in many places. Specimens are almost invariably covered with nullipores and other growths, rendering them most unsightly till these are removed. What the use of the labial tooth can be is mere conjecture. It cannot be for purposes of spearing or securing its prey—a Molluscan Narwhal—nor for digging food out of the recesses of the rocks, for it is not placed in such a position as to give the shell any leverage, and, moreover, were it of any use, we might expect to see in it signs of wear and tear, epecially in old specimens, (I have one aged well-grown form with the tooth ½ inch long), but it always looks sharp and strong in any shells that have been procured alive.

The shells of the subgenus *Cerostoma* of *Murex* (L.), also *Monoceros* (Lam.), and *Chorus* (Gray), all possess a similar tooth, but in none is so high or typical a development reached as in *Latirus cingulatus* (Lam.)

Another interesting point about this shell is its slightly raised and rough olive brown bands, from which it takes its specific name: these are regular and equidistant; and, speaking generally, the species presents but little variation.

(IX.) *Geographical Distribution.*—When, three years ago, I gave some notes upon the genus *Cypræa*,* I prepared a slightly modified version of† Mr. A. R. Wallace's six regions, which, considering the very wide range of certain shells, *e.g.*, *Peristernia nassatula*, causes the small alterations proposed advisable, especially as these regions were devised more with a view to elucidate the distribution of terrestrial than marine life.

Several species are of doubtful locality, and, actually, a few, even now their area is extended, fall into two or more sections, and are thus counted twice.

LATIRUS AND PERISTERNIA.

Region.	No. of Species.	Region.	No. of Species.
(*a*) *Nearctic; i.e.*, United States & Canadian Coasts, Atlantic, and Pacific.	8	(*d*) *Ethiopian;* including African Coast, Madagascar and the Mascarene Islands in the Pacific, C. de Verdes and Canaries in the N. Atlantic, also S. Helena and Ascension Isles in S. Atlantic.	38
(*b*) *Neotropical; i.e.*, Mexico, and Central American Coasts, Gallapagos Isles, W. Indies and South America, Atlantic and Pacific.	16	(*e*) *Australian;* here signifying Australia, Tasmania, New Zealand, and the Fiji Isles.	25
(*c*) *Palæarctic;* here simply including European Seas proper, with both shores of the Mediterranean, Madeiras and Azores.	3	(*f*) *Oriental;* embracing Chinese Seas and Japanese, E. Indies, Polynesia, Persian Gulf, and Red Sea, also all Indian Seas and Ceylon.	55

* *Vide* Vol. I., 4th Series, *Mem. and Proc.* Manchester L. & Phil. Soc. pp. 184, sqq.

† *Vide The Geographical Distribution of Animals*, 2 Vols., by Alfred Russel Wallace.

It is curious how deficiently represented in local lists of collectors' findings, the genera under discussion are. For instance, in the list of shells found in the Mergui Archipelago, Bay of Bengal, described by Prof. E. von Martens, none are mentioned (*Proc. Linn. Soc.* XXI., pp. 155 sqq.), the *Taron dubius* had not then been discovered. None occur in either Prof. Martens' or Mr. Hutton's Lists of New Zealand shells.* None occur in either the lists compiled by Mr. Sylvanus Hanley in "Ceylon," by Sir J. Emerson Tennent, nor, again, in Mr. A. W. Langdon's lists of the shells of the same Island (*Journ. Conch.*, I., p. 71). Mr. Brazier, in the same publication (Vol. II., p. 186 sqq.,), only mentions one species *P. incarnata* (Desh), in his account of the marine Fauna of Fitzroy Island, Australia. The Rev. Philip P. Carpenter, in 1853, names 4 species as occurring in the Gulf of California, 5 on Central American Coasts (Pacific), 6, including the unique *L. tumens* (Cpr.), from Panama, 3, viz., *L. ceratus*, *tuberculatus*, and *varicosus*, from the Gallapagos Isles.† The total number of species on the North and Central Pacific Coasts of America being 11, some found of very wide distribution. In the Gulf of Mexico but few occur; at the Island of Curaçoa, north of Dutch Guiana, Dr. Epp has lately found two species, *L. distinctus* (A. Ad.) and a new form, *L. Eppi*. When I was on the coral reefs, off the south coast of Florida, in 1872, I only collected two species of *Latirus*,‡ one being *L. cinguliferus* (Lam.), var. *Knorrii* (Desh.), the

* Cat. *Marine Moll.* of N. Zealand, 1873, by F. Wollaston Hutton. *Crit. List Moll.* of N. Zealand contained in European collections by Prof. Edouard von Martens, M.D., etc., 1873.

† *cf.* C. B. Adams, Ann. N.H. Lyceum of New York, 1852, p. 355 sqq., in which a list of Panama and Taboga Marine Shells is given.

‡ *cf. Bulletin*, U.S.A. Nat. Museum, No. 37, by W. H. Dall, 1889, who enumerates in this Catalogue of the Marine Molluscs of the South Eastern Coast of N. America, 5 sp. of this genus, viz.: *ocellatus*, *brevicaudatus*, *cinguliferus*, *Capehatteraicus*, and *infundibulum*.

other a very interesting new form, like *L. infundibulum* (Gmelin) in miniature, called by me in MSS. and afterwards described by Mr. G. B. Sowerby (*Proc. Zool. Soc.*, 1878), as *L. Cayohuesonicus*, after the Island of Cayo Hueso or Key West. Of this small species I give a figure (Fig.2). No species occur in Europe proper, excepting the Mediterranean Fusus, now *Aptyxis Syracusanus* (L.), and *Latirus lignarius* (L.) (= *Fasciolaria Tarentina*), though other Fusi occur there, which are not dealt with in this paper. *Boreofusus Berniciensis* (King) occurs on the Norwegian and North British coasts, and *Latirus armatus* (Ad.), having occurred both at Madeira and Teneriffe, may probably reward the future dredgers still further north—as, now that we hear of *Cassidaria Tyrrhena*, for instance, dredged off the S. coast of Ireland, there is no saying what treasures are only awaiting the man, and the opportunity. Our British lists will, in time, probably be largely increased. The *L. armatus* (Ad.), is a most exceptionally interesting species, and one long misunderstood. Consult the Rev. R. Boog Watson's full report of it (*Voy. Challenger Zool.* Vol. XV., p. 243) under the name of *Fasciolaria armata* (A. Ad.), formerly *L.* or *Chascax Maderensis* (Watson). Only three *Latirus* proper, *L. Strangei* (A. Ad.), *L. contemptus* (Ad.), and the above *L. armatus* (Ad.), were dredged in this expedition, during the whole of its protracted wanderings, and in two out of the three (for I have examined the specimens) they are most meagrely and poorly represented.

The bulk of *Latirus* and *Peristernia* are found in the E. African and Asiatic Islands—notably Mauritius, where, on Barkly Island,* beautiful specimens, especially of the smaller kinds, with many new species, have been obtained, mainly by the exertions of M. Robillard, Sir H. Barkly, Sir

* *c.f. Subtropical Rambles in Mauritius*, by Mr. N. Pike, where an account of this recently-formed island, named after the then Governor of Mauritius, Sir H. Barkly, is given.

David Barclay, and Mr. Nicholas Pike. New Caledonia, the Fiji and Society Islands, also supply a great many; and one very beautiful little species, of which there are two specimens in the British Museum, is being described in this paper under the name of *Peristernia Iniuensis*, from Iniue or Savage Island, where it was collected many years since by Mr. Perry.

The coasts of Africa proper are strangely deficient in species: though Mr. G. B. Sowerby has recently, in the *Journal of Conchology*, 1886, described *L. Bairstowi* and *L. Rousi*, both good species from Port Elizabeth—and one from Natal (*P. leucothea*) is described in this paper. The Philippine Islands, of course, supply a fair quota; but I have never seen a full list of species obtained from that extremely prolific quarter.

Some of the finest species occur there, *e.g. craticulatus* (L.) *lanceolatus* (Reeve), *polygonus* (Gmel.), *recurvirostris* (S. and W.), *Peristernia castanoleuca* (T. C.), *spinosa* (Mart.), *nassatula* (Lam.), etc., but many of these are of very wide distribution. Indeed, it is quite remarkable how the areas of a few kinds extend thousands of miles,* while others are very restricted in their distribution. Japan boasts of the fine *L. Nagasakiensis* (E. A. Smith), nearly allied to *craticulatus*, but I think distinct. A few are found in Australia proper, *P. Brazieri* (Angas), a species of slightly doubtful affinity, *L. gibbulus* (Gmel.), *smaragdulus* (L.), etc. In the Rev. A. H. Cooke's report on the Mollusca dredged by the late R. Macandrew, Esq., in the Gulf of Suez, only *Latirus turritus* (Gmel.) is mentioned besides *L. pulcher* (Reeve) = *Engina pulchra*.

(X.) *Habits and Localities where found.*—The localities in which these molluscs usually congregate, are in rocks

* Since writing this paper, Mr. G. B. Sowerby has forwarded me, for identification, a specimen of *Peristernia Smithiana* (described in this paper as new, from the island of Mauritius) as having come from Aden.

and amongst algæ at low water mark; some of them are predaceous, living on smaller molluscs. Not many, indeed, are found at any depth. The few specimens brought home by the "Challenger" expedition, were obtained at the following soundings:—

Latirus armatus (Ad.), 75 fathoms, off Tenerife.
" *contemptus* (A. Ad.), 15 to 25 fathoms, Amboyna.
" *Strangei* (A. Ad.), 12 fathoms, Levuka, Fiji.

and of these three, *L. contemptus* (A. Ad.), is probably one of the *Muricidæ*, and ought to be expunged from this series.

The extreme brightness and gay colouring of some of the smaller species are noteworthy, and they no doubt live more freely, and in greater variety and beauty in shallow coral lagoons, where the water is more or less still. Many of the larger *Latiri* are unsightly objects, being, as a rule, covered with nullipores and various growths—in fact, several of the species have to be cleaned to reveal their real beauties.

As is often the case with gaudily-painted shells, they are taken possession of by certain *Paguri* and other Hermit crabs, and several specimens I have of *P. castanoleuca* (Tapp.-Canefri.) and other *Peristernidæ*, though in very good condition, have their labial columella quite worn away from this cause.

(XI.) *Criticisms on Mr. Tryon's Monograph.*—The latest monograph of these genera is that of the late Mr. G. W. Tryon, junr., (*Man. Conch.*, Vol. III., pp. 79—97, 1881), in which he treats of three genera *Latirus*, *Peristernia*, and *Leucozonia*. He has, unfortunately, fallen into many errors, which have mainly arisen through his attempting to do too much, and in too great haste, and not seeking collaboration more frequently. This latter course he adopted only in *Cypræa* and *Solarium*, and with very beneficial results in both cases. So far as he was able to consult the important collections under his charge at the Museum of the

Academy of Science, Philadelphia, he has usually judged correctly, and, at all events, his conclusions are worthy attention ; but the off-hand way in which, without having even taken the trouble to *enquire* about the type specimens in the Museums of Europe, he merges forms unknown to him, as synonyms or varieties of species altogether unlike, or ignores them altogether, militates much against the abiding usefulness of his ambitious work—a work, in which there are many good points, with much to recommend it.

For instance, he strings together, as mere 'nomina nuda,' without a word, the following species, as unidentifiable, *all* of which I have found in the British Museum collection, and have figured one or two of them in the accompanying plate.

Latirus Zea (Mor.). A variety of *L. sanguifluus* (Reeve). There is a specimen in the British Museum, almost typical with *sanguifluus*. It should, therefore, be perhaps, rather considered a synonym.

L. neglectus (A. Ad.) = *Peristernia neglecta*, near *P. nassoides* (Reeve).

L. armatus (A. Ad.)=Chascax (Watson). A most well-marked species, and the omission of which from any monograph tends much to injure that treatise. It seems a link between *Latirus* proper and the *Leucozoniæ*. It is the same as *Latirus spinosus* (Gray), which Mr. Tryon mentions under *Peristernia*, as a doubtful form.

L. elegans (A. Ad.) near *attenuatus*, which I do not, as Tryon does, consider a variety only of *infundibulum*. *L. distinctus* (A. Ad.), (fig. 3), a well-marked ponderously sculptured shell, dark orange colour, from the Gulf of Mexico, bearing some relation to *L. armatus* on the one hand, and *L. rudis* on the other. It is very extraordinary that this shell had not, in 1881, reached Philadelphia.

L. Strangei (Ad.). Figured in the "Challenger" Report, Vol. XV., allied to *P. scabrosa* (Reeve).

Turbinella striata (Gray), another species unidentified by Mr. Tryon, is *P. crocea* (Reeve and Gray).

Turbinella sulcata (Gray) is a synonym of *P. scabrosa* (Reeve).

* * * * *

Again, *Latirus candelabrum* (Reeve), merged as a variety of *Polygonus* (Gmel.) by Mr. Tryon is, in my opinion, a sufficiently good species.

L. modestus (Anton). It may be difficult to trace Anton's species from mere descriptions, but it is certainly not safe, without more evidence, to place it as equalling *L. spadiceus* (Reeve), and to sink the latter name as synonymic only.

Turbinella castanea (Gray). The specimen is a variety of *T. cingulifera* (Lamarck).

Latirus tumens (Carpenter) (Fig. 14). If Mr. Tryon had seen the unique specimen in the National Museum, South Kensington, from Mr. H. Cuming's collection, and also examined *L. gracilis* (Reeve) at the same time, he would never have committed himself in the way he has done in his remarks.

L. brevicaudatus (Reeve) and *filamentosus* (Koch). Two distinct species, judging by specimens I have examined, in the British Museum.

Of two species, *Latirus annulatus* (Bolten) and *L. vexillulum* (Reeve), Tryon makes no mention—he has, therefore, accidentally omitted them.

Leucozonia rudis (Reeve) is, I think, sufficiently distinct from *L. cingulifera* (Lamarck), though I agree with Mr. Tryon in the other subspecies. Nor do I think *Lagena subrostrata* (Gray) otherwise than a *Cantharus* : the dentition alone will tell for certain.

Peristernia Forskälli (T. C.) seems, at all events, a good species, though allied to *P. nassatula* (Lamarck).

Mr. Tryon has fallen into strange mistakes too, with regard to the *Engina*-like forms I have excluded from the

genus. He makes *Ricinula pulchra* (Reeve), or *Peristernia pulchra* of some authors a variety of *P. incarnata* (Desh.), one of the most extraordinary conclusions that has ever been drawn by any writer, and also describes *Peristernia Carolinæ* (Kien) twice, once under *Peristernia*, and again under *Engina* (Gray), where I agree it had better find a location.

Peristernia chlorostoma (Sowb.). Mr. Edgar Smith has given me the benefit of his valuable opinion as to this perplexing species and its allies; marking out four species (*vide* Catalogue), all of which have been unhesitatingly swamped by Mr. Tryon under this name.

I think *P. Caledonica* (Petit) and *infracincta* (Kobelt), also *Marquesana* (A. Ad.) distinct. They, again, are all grouped as synomyms of *P. ustulata* (Reeve) in the Manual.

I am almost inclined to agree with Tryon that *P. nassoides* (Reeve) may turn out a *Nassaria*.

The columellar plaits are absent, and the 'facies' of the shell is more like that genus. *P. pulchella* (Reeve) is, however, nearly allied, and as that is a true *Peristernia*, it would not be well to sever them at present.

I hope it will not be thought that I have been wanting in charity towards the memory of Mr. Tryon by the foregoing remarks. I fully recognize the difficulties he had to contend with, and only wish he had consulted the museums on this side before entering on his work, more assiduously. The later volumes seem more carefully compiled, and freer from such errors as I have been expatiating on, than the former.

(XII.) *Remarks on the Sequence adopted.*—Taking firstly *L. aureocinctus* (Sowb.), as the simplest form of the genus with elongated spire, many whorled, canal very short, we pass at once to *craticulatus* (L.) and its congeners, *squamosus* (Pease), being the only alien form possessing

what is an unique occurrence in the genus, a thick white band below the sutures, producing at regular intervals a strong, short white spine. This is allied in other ways to *L. prismaticus* (Mart.), whose iridescent epidermis is discussed in another place. The ancient and widely-spread *L. turritus* (Gmel.), of brick-dust colour, only slightly noduled, and decorated with regular transverse lines, affords many links of kinship with *L. brevicaudatus* (Reeve), an elegant shell with extremely short beak, and transverse brown-lined painting, showing, however, a marked transition through *L. Syracusanus* (L.), (formerly *Fusus*), and *L. filosus* (Gmel.), to one of the most conspicuous of the genus, *L. infundibulum* (Gmel.) Here the acme of the species with whitish ground colour and red varied transverse lines seems to be attained. In close proximity to this must be placed the most fusoid of the group, *L. lancea* (Gmel.), a shell with a very prolonged canal, and all the external attributes of a *Fusus* of the "*Colus*" section, though its texture and ribbing are markedly Latiroid, let alone the presence of columellar plaits, while *L. angustus* (Sm.), and *Cayohuesonicus* (Sowb.), (fig. 2.), are much like *infundibulum* in miniature. A natural sequence now brings us to three or four species from the Western Coast of N. America, all much alike: *L. castaneus* (Reeve) being the type. Heavy shells are they, with more or less prolonged canal, and a peculiar obliquity or rather sinuosity of the outer lip, and more or less obscure transverse ribbing, *L. castaneus* being smoother than *varicosus* and *acuminatus*, and standing next to *L. nodatus* (Martyn), that large and beautiful species, so conspicuous for its pink or pale violet mouth, and fawn coloured epidermis, smooth with rounded concentric nodules. The *Fasciolaria lignaria L.* I place by this, a thinner shell it is true, but with, to some extent, the same characters; the canal in this species is similar to the *L. polygonus* (Gm.) and its allies, all of which come next. This shell (*polygonus*) is perhaps

the earliest learnt by the student, being of extremely wide distribution, and a handsome, large, brightly variegated form. It forms the type of Swainson's subgeneric *Plicatella*, based upon characters which it is impossible to maintain: a few forms analogous to this, bring us to *L. recurvirostris* (Schub. and Wagner), which is a good link with *L. gibbulus* (Gmel.), to which we have already fully alluded as Montfort's type of the genus.

Closely allied to this, is the large and still unique *L. tumens* (Carpenter), so grievously misunderstood by Tryon, who thinks it must be a variety of *Gracilis* (Reeve). Of this, since it has never been figured, I am pleased to be able to give a representation (fig. 14).

Through *L. cariniferus* (Lamk) and *distinctus* (A. Ad.), a very beautiful form, till lately misunderstood, and also figured now for the first time (fig. 3), we are brought to *armatus* (A. Adams), well pourtrayed in Vol. XV. of the *Zoology "Challenger" Expedition*, (pl. 13, fig. 1), and which I have already alluded to, this leading to *L. ceratus* (Reeve), a very conspicuous W. American species with short canal, and angled whorls with large white concentric nodules, closely allied to *L. tuberculatus* (Brod), the first of the series hitherto included in *Leucozonia* (Gray). Through *triserialis* (Lam.), with rows of sharp nodules ornamenting its whorls, we pass to *ocellatus* (Gmel.), and its elongated form *nigellus* (Chemnitz). *L. cinguliferus* (Lam.) is the most variable of the genus; some forms are angulated approaching *rudis* and other species, but this variation only strengthens the line of sequence here, and the very smooth rounded *L. smaragdulus* (L.) and *L. leucozonalis* (Lamk.) closely show their affinity. A slight hiatus might be thought by some to occur between *smaragdulus L.* and *cingulatus* (Lamk.), but I think the shells bear exactly the same principia of character through *leucozonalis*, as there is an evident sign of a labial tooth, though I do not perceive any such

attempts in *L. smaragdulus*. *L. amplustre* (Mart.) naturally follows, by an easy transition through some species hitherto placed in *Peristernia*, closing the genus with *L. vexillulum* (Reeve), which, in its turn, has some connection with one of the first species, on the list of *Peristernia*, *e.g. castanoleuca* (Tapperone-Canefri), better known by the superseded name *Philberti* (Recluz).

This very attractive little shell has affinities on the one hand with *P. spinosa* (Martyn), and *nassatula* (Lamk.), and on the other with *Australiensis* (Reeve), placed last almost in the series.

Through *spinosa* (Martyn) in which the spires on the transverse riblets are very prominent, we come to the beautiful and variable *nassatula* and its allies. This shell, the most beautifully delicate, perhaps, of all the species is, when in good condition white, occasionally variegated with fuscous-brown, the interior of the mouth and columella varying from rose pink to pale purple. *P. lirata* (Pease), *gemmata* (Reeve), are shells which it is not very easy to assign to quite a natural place. Indeed, it has occurred to me there may be a closer connection with *Latirus prismaticus* than one would admit at present. I have spoken about the similarity of the epidermis characters in these two species, and we have yet to learn the dentition of them all.

In *P. decorata* (Adams), well redescribed by Mr. Edgar Smith, in *P.Z.S.*, 1878, p. 812, and the newly-described *mannophora*, *hilaris* (figs. 4 and 5), and allies, we have a beautiful moniliform arrangement of the beading of the whorls just below the sutures, and these forms naturally lead to that group of which *P. pulchella* (Reeve) *maculata* (Reeve), *Smithiana* (sp. nov.) may be considered the types. *P. nassoides* (Reeve) is a somewhat anomalous kind, allied nearly to *pulchella*, but possessing certain *Nassarioid* peculiarities, suggesting the possibility of relegating it eventually to the genus *Hindsia*. There is no sign here of

columellar plaits. Through *P. flavida* (Ad.) (fig. 5) and *Mariei* (Crosse) we approach *P. incarnata* (Desh.), a well-marked species of gaudy coloration, also *infracincta* (Kobelt), so allied to it that I cannot but place it here, though for both it and *annulata* (Bolten) (fig. 1) some conchologists might, and perhaps with good reason, find a place in *Latirus*, near *Syracusanus L.* *P. Brazieri* (Angas) like *infracincta* in form, is conspicuous for absence of columellar plaits.

Now begin the range of mostly small species allied to *ustulata* (Reeve), the majority of which have an indigo or brown stain at the base; there is more variety here, and more difficulty, than in other sections of the genus.

Lastly come *P. chlorostoma*, *striata*, and allies; a very beautiful little assemblage of shells, and extremely variable. One form, *Selinæ* (fig 7), I have given a separate description to in this paper, a very beautiful form, allied closely to *stigmataria* (Ad.), which seems near *P. Australiensis* (Reeve), in its disposition of markings. *P. Iniuensis* and *Wagneri*, which come last, both have crenulated outer lips; I therefore admit them as true *Peristerniæ* with a little diffidence, there being many points, it is true, in common, but also certain *Engina* relations which we wait for the knowledge of the lingual ribbon to verify.

I am sure, however, that *Pauluccia* (Kobelt), *pulchra* (Reeve), *Carolinæ* (Kien) = *Ricinula bella* (Reeve), and others formerly included in this genus are *Enginæ*, and so exclude them here.

One instance will suffice. *P. Carolinæ* (Kiener).

It will be noticed that by the Ricinula-like or columbelloid mouth, and the distinctly different line of painting and ribbing, that there is much more affinity between them and say *Engina histrio*, than with any *Peristernia*. The dentition of *Engina* is widely distinct, and it is to be wished that some student would make a special study of

these small, often very beautiful, forms, at present arranged haphazard under the genera *Murex*, *Purpura*, *Ricinula*, *Sistrum*, *Columbella*, *Peristernia*, and *Engina*.

(XIII.) *Descriptions of New Species.*

1. LATIRUS EPPI, *sp. nov.* (Fig. 11).

L. testâ ovato-fusiformi, crassâ, fulvo-brunneâ, anfractibus læribus, longitudinaliter costatis, nitentibus, transversim obscuré filo-liratis, liris ad suturas distinctioribus, canali subproductâ, spiraliter liratâ, aperturæ fauce sulcatâ, albescente, columellâ quadriplicatâ, albâ.

Long. 24 mill.

Lat. 10 „

Hab. Insula Curaçoa (*Dr. Epp.*)

This very interesting addition to the genus, is at present an unique shell, and forming part of the collection of the Leyden Museum, Holland. It has been kindly forwarded me by Mr. M. M. Schepmann, of Rhoon, Rotterdam, with the request that I would describe it, at the same time wishing that it should bear the name of its discoverer. In fact, Mr. Schepmann unites with me in joint authorship. The nearest approximations to this species are undoubtedly *L. castaneus* (Reeve) and *acuminatus* (Kiener) from both of which, however, it can easily be differentiated. Though so small for one of this section, the specimen is full grown, and slightly worn, the transverse liræ would, in a younger specimen, be regularly distributed over every portion of the whorls.

2. LATIRUS FORMOSIOR, *sp. nov.* (Fig. 16).

L. testâ gracili-fusiformi, fulvo-ochraceâ, apice roseo, anfractibus octo, rotundatis, elevato-striatis, striis arctè et regulariter tranversim cingulatis, longitudinaliter plicato-

costatis, costis rotundatis, canali subrecurvâ, aperturâ intus liratâ, columellâ quinqueplicatâ albescente.

Long. 30 mill.

Lat. 11.50 „

Hab. ?

A very beautiful shell, more so than its nearest congener, *L. fastigium* (Reeve), the comparison with which in this respect is hinted at in the specific name. It differs from this species in the more rounded whorls, greater regularity of the longitudinal ribs, fewer whorls (there are nine in my specimen of *fastigium*) and less slender attenuation of form.

I fancied I had, at one time, seen another specimen in the National collection, but Mr. E. A. Smith assures me I must have been mistaken.

The type is in my collection.

3. PERISTERNIA MANNOPHORA, *sp. nov.* (Fig. 4).

P. testâ subfusiformi, ochraceâ, anfractibus septem, angulatis, longitudinaliter regulariter costatis, costis transversim liratis, liris infrâ suturas duabus, ultimo anfractu tribus, nitidè moniliformibus et albotuberculatis, aperturâ ovatâ, labro simplici, columellâ triplicatâ.

Long. 20 mill.

Lat. 8 „

Hab. Madagascar.

Though allied to the next species (*P. hilaris*), this little shell is, in several particulars, quite different. The transverse liræ are not so close nor so deeply sulcated between, and the first liræ below the sutures are more irregularly beaded with necklace-like nodules, and the mouth is more ovate.

Represented at present by a unique specimen, in the National Collection, South Kensington.

4. PERISTERNIA HILARIS *sp. nov.* (Fig. 6).

P. testâ subfusiformi, fulvo-aurantiâ, anfractibus septem, conspicuè ad suturas angulatis, longitudinaliter multicostatis, liris transversim candidis arctè complexis, infrà suturas duâbus, ultimo anfractu tribus, moniliformibus;—sphærulis æquis, nitidis, labro simplici, aperturâ subangustâ, oblongâ, columellâ plicis tribus instructâ.

Long. 19 m.
Lat. 9 „
Hab. Mauritius.

One of the most beautiful of the smaller members of the genus. The ground colour is a deep orange, and the clean cut and close-lying white liræ transversely cross the whorls, affording a pleasing contrast. The two or three liræ immediately below the sutures are decorated with shining white round beads, of almost equal size, regularly concentrically disposed.

One specimen in the National Collection, South Kensington, *P. Kobeltiana* (Tapp. Can.), a very beautiful form from Mauritius, is a larger ally of this species.

5. PERISTERNIA CANTHARIFORMIS, *sp. nov.* (Fig. 12).

P. testâ gracili, elongato-fusiformi, ad basin subrecurvâ, anfractibus octo, longitudinaliter irregulariter costatis, liris, binis transversim multicinctis, albidâ, ad costas hic illic aurantio-suffusâ, aperturâ simplici, columellâ quadriplicatâ, albescente.

Long. 31 mill.
Lat. 11 „
Hab. Mauritius.

A most graceful and delicate species, unlike any other known to me, though slightly resembling the next to be described, from which it abundantly differs in many particulars. The extremely attenuated and graceful form, superficial character of the ribs, the delicate orange chestnut colouring, impart a very lively bright appearance to the

shell, which is not unlike *Cantharus gracilis* (Reeve) in form superficially suggesting the trivial name.

Type at present unique in my collection.

6. PERISTERNIA CREMNOCHIONE *sp. nov.* (Fig. 9).

P. testâ subattenuatâ, fusiformi, anfractibus septem, anguliferis, longitudinaliter costulatis, ad angulis costarum præcipuè albofusis sulculis plus minusve binis, transversim rugulosis, fasciâ fulvo-brunneâ ad suturas et in medio ultimo anfractu insigni, columellâ triplicatâ, aperturâ pallidâ, ovatâ, labro subangulato.

Long. 24 m.

Lat. 11 m.

Hab. Mauritius.

This seems a variable little species, of which I have seen a good many specimens—the central brown fascia is, however, present in them all, the number of ribs, and their more or less angularity vary immensely: the ribs of one specimen I have—and which at one time was thought to be new—are quite destitute of any angles whatsoever, and the style of painting differs, giving the semblance of pseudo-varices. This may be called variety β. *photiformis*, the general appearance resmbling *Phos roseatus* (Hinds), in miniature. Of this species the type figured is one of two in the British Museum, South Kensington. I have received, through Mr. G. B. Sowerby, four other specimens mostly differing, as I have said, in the style of painting. This species and the last belong to the same section of the genus as *P. pulchella* (Reeve) and *P. maculata*, also of Reeve.

7. PERISTERNIA SMITHIANA, *sp. nov.* (Fig. 8).

P. testâ fusiformi fulvo-ochraceâ, ad angulos costarum pallidiore, anfractibus septem, interdum octo, longitudinaliter forticostatis, liris et costis tranversim alternantibus, ad suturas rugulosis, in medio angulatis, canali brevi, subrecurvâ,

aperturâ intus striatâ, labro simplici, columellâ obscurè triplicatâ.

	sp. maximæ.	sp. minimæ.
Long.	38 m.	28 m.
Lat.	18 „	12 „

Hab. Mauritius. Aden.

Of uniform tawny ochreous colour, paler at the points where the ribs are crossed at the angle of the whorls by the transverse riblets. It varies a good deal in size, and the five specimens I have, embrace all the differences between the extreme measurements here given. It seems to belong to the same group as the last species described.

I have had six specimens of this till now undescribed shell for many years, obtained at the sale of the collection of Mr. W. J. Hamilton, in March, 1870. One of these specimens, the type figured, is now in the National Collection, South Kensington. I have unusual pleasure in associating with this species the name of Edgar A. Smith Esq., F.Z.S., Curator of the Molluscan Department, British Museum, who has given me much valuable and valued assistance in the preparation of this historical account of *Latirus* and *Peristernia.*

8. PERISTERNIA RETIARIA, *sp. nov.* (Fig. 13.).

P. testâ fusiformi, pallidè flavo-ochraceâ, crassiusculâ, anfractibus septem, rotundatis, subventricosis, longitudinalitèr costatis, costis subangulatis, indistinctè fulvo-punctatis, costulis transversim cingulatis, labro tenui, aperturâ oblongâ, basi nigro-cæruleâ.

Long. 20 m.

Lat. 8 „

Hab. Mauritius.

A delicate looking, though non-transparent shell, and of rather thicker substance than one would imagine, of a pale ochraceous colour, with indigo blue base, the ribs are very

numerous, and crossed in a somewhat latticed style of network with smaller riblets, the main longitudinal ribs being dimly spotted with fulvous dots, hardly visible without the aid of a lens. There is also a dark line at the sutures. It comes under the *ustulata* section, but is distinct from any of the group.

Two specimens, one operculated, collected by M. Robillard at the locality just mentioned above, are in the National Collection.

9. PERISTERNIA LEUCOTHEA, *sp. nov.* (Fig 15).

P. testâ subpyramidali, ad apicem multum attenuatâ, anfractibus septem, longitudinaliter multicostatis, transversim liris tenuibus arctè cingulatis omninò albescentibus, aperturâ effusâ simplici, albâ, labro intus sulcato, columellâ obscurè triplicatâ.

Long. 18·50 m.

Lat. 8 m.

Hab. Port Natal, S. Africa.

A curious and very neat little shell, of chaste device. I have found a specimen very nearly resembling my own, in a tablet in one of the drawers underneath the table cases in the National Collection, where it had been mounted years ago with a specimen of *P. crocea*, and the locality given 'Natal,' and several specimens have recently been received from the same locality.

10. PERISTERNIA SELINÆ, *sp. nov.* (Fig. 7).

P. testâ fusiformi, subpellucidâ, elegantissimâ, anfractibus septem, rotundatis, albis, ad suturas castaneo-suffusis, longitudinaliter costatis, lirulis transversim cingulatis, in medio inter costas maculis castaneis cincto, apice nigro, columellâ quadriplicatâ, basi castaneo-suffusâ, labro intus sulcato.

Long. 27 mill.

Lat. 14 „

Hab. Ins. Sandvichenses.

This is an extreme form of *P. stigmataria* (A. Ad.), from which it differs in its greater elegance of form, delicacy of appearance, and more regular transverse liration. It is impossible, in any figure, to do justice to the extreme beauty of this shell. I have two specimens in my collection, from the larger of which the figure in the plate is taken, and there are some specimens in the National Collection, from the locality mentioned above.

11. PERISTERNIA INIUENSIS, *sp. nov.*, (Fig. 10).

P. testâ ovato-fusiformi, roseo-tinctâ, anfractibus sex, subventricosis, longitudinaliter plicato-costatis, tranversim crassisulcatis, apice roseo, labro intus crenulato, aperturâ ovatâ, columellâ fortiter triplicatâ.

Long. 7·50 mm.

Lat. 3 „

Hab. Iniue I. (or Savage Isld.), W. W. Perry, Esq.

An exceedingly minute, but extremely beautiful little species, and quite unlike any hitherto described, although it approaches some forms hitherto included in *Peristernia*, which we are inclined to refer to *Engina* (Gray) it yet possesses characteristics which would point at the suitability of its retention in this genus. Both the specimens known, are on a tablet in the National Collection, labelled as above, and both are alike in the exquisite pink suffusion which renders it, though the smallest, quite one of the gems of a very beautiful genus.

(XIV). *Total Number of Species.*—In the last Catalogue of the late F. Paetel (Berlin, 1887), the whole of the three genera are united under the title *Latirus* (Montfort) and 144 species, besides varieties and synonyms, are mentioned. Of these we expunge 46, either as reduplications, mistakes, synonyms, or as belonging to

other genera, or, as unidentifiable. A list of the chief of these will be given at the end of this paper, after the Catalogue. Suffice now to say that to the 98 good species, two are added, viz., *Latirus lignarius* and *Syracusanus*, formerly *Fasciolaria* and *Fusus* respectively, and 11 new species, bringing up the total to 111 species, or the segregate *Latirus* 62, *Peristernia* 49.

(XV.) LIST OF THE DESCRIBERS OF RECENT SPECIES AND VARIETIES OF LATIRUS AND PERISTERNIA.

Adams, H. & A.
Anton, H. E.
Angas, G. F.
Bernardi, A. C.
Broderip, W. J.
Carpenter, P. P.
Chemnitz, J. H.
Crosse, H.
Deshayes, G. P.
D'Orbigny, A.
Dunker, W.
Fischer, P.
Gould, A. A.
Gray, J. E.
Hombron.
Hutton, F. W.
Jeffreys, J. Gwyn.
Kiener, L. C.
King
Kobelt, W.
Koch.
Küster, H. C.
Lamarck, J. B. de
Lesson
Linnæus, C.
Martens, E. von
Martini, F. H. W.
Martyn.
Mawe.
Melvill, J. C.
Montfort, Denys de
Morch, O. A.
Nuttall, T.
Pease, W. H.
Petit de la Saus-saye, S.
Philippi, R. A.
Reeve, Lovell A.
Schepmann, M. M.
Schubert.
Schumacher, C. F.
Smith, Edgar A.
Souverbie.
Sowerby, G. B. (Sen.)
Sowerby, G. B.
Tapparone-Canefri, C.
Troschel, F. H.
Tryon, G. W. (Jun).
Valenciennes, A.
Wagner.
Watson, R. Boog.

XVI.

A CATALOGUE

OF THE SPECIES AND VARIETIES OF

LATIRUS [Montfort 1810] and immediate allies.

Revised to March, 1891.

By JAMES COSMO MELVILL, M.A., F.L.S.

I. TARON [Hutton, 1882].

1. *T. dubius* (Hutton). Zool. Rec. XX., Moll. p. 42. 1882. Urosalpinx dubius. sec. Tryon. — New Zealand.

II. BUCCINOFUSUS [Conrad., 1867].

Syn.: BOREOFUSUS [Sars.], 1878.

1. *B. Berniciensis* (King). Ann. Mag., p. 246, 1846. FUSUS sp. — Anglia et Norvegia.

III. LATIRUS [Montfort, 1810].

Syn.: MUREX (pars.) (Linn.) 1767. TURBINELLA (Lam.) 1790. POLYGONA (Schumacher), 1817. PLICATELLA (Swainson), 1842. LEUCOZONIA (Gray), 1847. LAGENA (Schum), 1817.

Synonyms.

1. *L. Noumeensis* (Crosse). J. de Conch, XVIII., 247, 1870, XIX. 1871. — N. Caledonia.
2. *L. scaber* (Souverbie). J. de Conch, XVII., 1869, XVIII., 1870. — ,,
3. *L. Rousi* (Sowb.). Journ. of Conch., Vol. V., p. 8, 1886, Vol. VI., p. 1, t. 13. — Port Elizabeth, Africa Mer.
4. *L. aureocinctus* (Sowb.). Proc. Zool. Soc., 1875, p. 129, t. 24, f. 2. — Mauritius.
5. *L. lautus* (Reeve). Conch. Icon. IV., f. 73, 1847.
6. *L. craticulatus* (Linn.). Murex craticulatus (Linn.). Syst. Nat., Ed. XII., 1224, 1767. — Mare Erythræum, Oc. Ind. et Pacificus, Borbonia, Polynesia.
7. *L. Nagasakiensis* (E. A. Smith). Proc. Zool. Soc., 482, t. 48, f. 7, 1880. — Japonia.
8. *L. sanguifluus* (Reeve). Zea (Mörch). — Guinea.
   Conch. Icon., IV., f. 58, 1847.
   β. *fallax* (Kobelt) sp. nodulatus (Pease, W. H.) — Ins. Marquesas.
   Küster Conchyl. Cab. 80, t. 19, f. 3.
9. *L. squamosus* (Pease). Proc. Zool. Soc., 240, 1862. — Baker's I. Polynesia.

10.	*L. prismaticus* (Martyn). Univ. Conch., Vol. II., p. 2. *c.f.* Reeve Conch. Icon. IV., f. 25.	Buccinum prismaticum (Mart.).	Ralick & Radick Ins. Ins., Kingsmill, et Tonga. (W. H. Pease.)
11.	*L. turritus* (Gmelin) Syst. Nat., 3456, 1790.	subfuscus (Martini). tæniatus (Desh).	Suez. (c.f. A. H. Cooke), Macandrew Catalog., Mare Erythræum, Australia, Mauritius, Insulæ Philippinenses.
	ß. *L. lineatus* (Lamk.). Hist., VII., p. 109.		Masbate I.
12.	*L. brevicaudatus* (Reeve). Conch. Icon. IV., f. 50, 1847.		Brasilia, Florida
13.	*L. filamentosus* (Koch). Küster, Conch., cab. 69, t. 9, f. 8.	intermedius (Koch?)	
14.	*L. spadiceus* (Reeve). Conch. Icon., Vol. IV., f. 44, 1847.		Panama, Acapulco, Fernando Noronha, (Ridley).
15.	*L. lyratus* (Reeve). Conch. Icon., Vol. IV., f. 13, 1847.		I. Camaguing, Ins. Philippinenses.
16.	*L. Syracusianus* (L.). Syst. Nat., XII., 1224, 1767 [Fusus sp.].	Aptyxis [Troschel.] Gebiss der Schnecken. 1868.	
17.	*L. filosus* (Schubert and Wagner). Conch., Cab. XII., 100, t. 227, f. 4019, 4020, cab.	ambustus (Gould). elegans (Gray), 1838.	Sierra Leone, Goree, I. Prince, Senegal, Africa, occ.
18.	*L. formosior* (Melvill), 1891.		?
19	*L. fastigium* (Reeve). Conch. Icon., f. 72, 1847.		Ceylon et Ins. Andaman, (Wilmer)[Ind. occid., Swift?]
20.	*L. rhodostoma* (Dunker). Mal. Blatt., VI., 238, 1860.		Japonia.
21.	*L. concentricus* (Reeve). Conch. Icon., Vol. IV., f. 2, 1847.		St. Elena, Colombia, occid. Acapulco.
22.	*L. Pfeifferianus* (Kobelt). Küster Conch., Cab. 71, t. 18.		Mare Indicum.
23.	*L. elegans* (Adams). Proc. Zool. Soc., 315, 1854.		?
24.	*L. gracilis* (Reeve). Conch. Icon., IV., f. 53, 1847.		Ad Oras Occid. Americæ Borealis.
25.	*L. alternatus* (Reeve). Conch. Icon., IV., f. 69, 1847.		
26.	*L. infundibulum* (Gm.). Syst. Nat., p. 3554, 1790.	Murex infundibulum (Gmlin). Fusus ,, Enc. Math. Polygona fusiformis (Schum). aculeiformis [Fusus].	Tortugas. Ind. occident.
27.	*L. lanceus* (Gmelin). Syst. Nat., 3556, 1790.	acus (Sowb. & Reeve) ,, lanceola (Reeve).	

28.	*L. angustus* (E. A. Smith). Zool. Coll. Alert., p. 52, t. V., fig. F.		Queensland.
29.	*L. Cayohuesonicus* (Sowb.). Proc. Zool. Soc., 796, 1878.		Key West (Cayo Hueso) Florida mer. detexit J. C. Melvill, 1872; S. Thomas I. (Swift).
30.	*L. Bairstowi* (Sowb.). J. of Conch., vol. V., p. 8, 1886; vol. VI. pl. 1., t. 14.		Port Elizabeth, Africa mer.
31.	*L. varicosus* (Reeve). Conch. Icon. IV., f. 6, 1847.	sanguineus (Mawe) ,, (Wood)	Ins. Gallapagos.
32.	*L. acuminatus* (Kiener). c. 28, t. 15, f. 12.	acuminatus (Wood).	Ins. Philippinenses (Cuming.)
33.	*L. Eppi* (Melv. and Schepmann), 1891.		I. Curaçoa, Sinus Mexicanus, (Dr. Epp).
34.	*L. castaneus* (Reeve). Conch. Icon., IV., f. 26, 1847.	acuminatus (Wood) non. Kiener.	G. California. Panama.
35.	*L. nodatus* (Martyn). Univ. Conch., II., t. 51.	Buccinum nodatum (Mart.) Murex rigidus (Wood). Turbinella rigida (Gray). Murex nodatus (Gmel.). Dillwyn cat.	Panama, Ins. Sandwichenses, Viti.
36.	*L. lanceolatus* (Reeve). Conch. Icon., IV., f. 12, 1847. Ad. and Reeve, Voy. Samarang, 42, t. 7, 1848		Ins. Philipinenses.
37.	*L. Robillardi* (Tapp. Canefri). J. de Conch., 1879, f. 318. Ann. Soc. Mal. Belg., 1880, XV. pl. 2, f. 12, 13.		Mauritius.
38.	*L. lignarius* (Linn.). Syst. Nat., XII., 1224, 1767.	FASCIOLARIA (Lam.) F. Tarentina (Lam.), 1790. Savignyi (Tapp. Canefri). unifasciatus (Wood).	M. Mediterraneum.
39.	*L. polygonus* (Gmelin). Syst. Nat., 3555.	Murex polygonus (Gmelin.). Fusus polygonus (Encycl. Meth.).	Ticao et Luzon, Ins. Philippinenses. Mascarenses, Mare Erythræum, ad. Ins. Perim, (J. J. Walker, R.N.). Cape Upstart (J. B. Jukes), Rodriguez I.
	β. tessellatus (Kobelt).		Vavaw, Ins. Tonga (Mus. Brit.).
40.	*L. Barclayi* (Reeve). Coch. Icon., IV., f. 20, 1847.		Mauritius.
41.	*L. candelabrum* (Reeve). Conch. Icon., IV., f. 9, 1847.		St. Elena, Columbia occ.
42.	*L. Amaliæ* (Kobelt). Küster Conch. Cab., 81 t. 19, f. 4, 5.		
43.	*L. recurvirostris* (Schubert and Wagner). Conch., XII., p. 100, f. 227.		Luzon I. (Mus. Brit.).
		MUREX filosus (Lamk.)	

44. *L. gibbulus* (Gmelin). Syst. Nat., 3557.	"Le Latire Orange." LATIRUS TYP. MONTFORT, 1810.		Australia.
45. *L. tumens* (Carpenter). Proc. Zool. Soc., 315, 1854.			America centr.
46. *L. carinifera* (Lamk.). Hist., VII., 108.			Ins. Viti.
47. *L. distinctus* (A. Adams). Proc. Zool. Soc., 315, 1854.			Curaçoa I. Sinus Mexicanus (Dr. Epp.).
48. *L. armatus* (A. Ad.). Proc. Zool. Soc., 314, 1854.	trochlearis (Küster).		Goree, Sierra Leone, Africa occ., Ind. occid.
β. *Madeirensis* (Watson). *c. f.* R. Boog Watson, Zool. Challenger Exped., XV., p. 243.	CHASCAX (Watson). propr. gen. Turbinella spinosa (Gray), Ann. and Mag. N.H. 1838, I. p. 28.		Madeira.
49. *L. rudis* (Reeve). Conch. Icon., IV., f. 51, 1847.			Ind. occidentales
50. *L. ceratus* (Gray). Zool., Beechey's Voyage, p. 114.			Ins. Gallapagos, Panama, Mazatlan (R. B. Hinds).
51. *L. tuberculatus* (Brod.). Proc. Zool. Soc., VII., 1833.			Ins. Gallapagos, Ind. occident.
52. *L. trisertalis* (Lam.). Hist., VII., 10.			I. S. Vincent, Africa occident: Bahia, Brasilia.
δ. *Hidalgoi* (Crosse). J. de Conch., XIII., p. 414, t. 14, f. 1.			
γ. *Stokesii* (Gray). Zool., Beechey's Voy., p. 114, 1839.			Porto Praya, C. de Verde Ins.
λ. *dubius* (Petit). J. de Conch., IV., p. 75, t. 2, f. 9, 10, 1853.			Fernando Noronha I. (Ridley), Ind. occident.
53. *L. cellatus* (Gmelin). Syst. Nat., X., 748.			
δ. *nigellus* (Chemnitz).		Fasiolaria cingulifera, Enc. meth., incultus (Gould)	Cedar Keys, Florida occ.:—ad Ind.: occident: Floridas.
54. *L. cingulifera* (Lam.). Hist., VII., 108.		Murex nassa (Gmel). (pars.)	Fernando, Noronha I. (H. N. Ridley), St. Vincent I. (Mus. Brit.), Gambia, Senegal, et Ind. occidentales.
δ. *Amerus* (Desh.). Anim. Sans. Vert., IX., 391.		Turbinella castanea (Gray). fuscatus (Gmel).	Key West, Florida mer (J. C. Melvill, 1872). Honduras.
γ. *Brasilianus* (D'Orb.). Voy. Amer. mer. 449, t. 77.		angulatus (Kobelt).	Brasilia, Ins. occidentales.
λ. *angularis* (Reeve). C. Icon., IV., f. 49, 1847.			,,
ε. *Kusanus* (Dunker). [Kobelt, 83].			,,
55. *L. leucozonalis* (Lam.). Hist., VII., 107.			Honduras.
		Buccinum smaragdulus (Linn).	
		,, rusticum (Gmelin).	

56.	*L. smaragdulus* (L.). 610.	Mus. Ulric.,	Lagena crassa (Schum). Turbinella rustica (Lam).	Ins. Philippinenses, Polynesia, Viti Is. Pt. Essington, Australia (Mus. Brit.)
			LEUCOZONIA, sp. (Gray).	
57.	*L. cingulatus* (Lamk.).	Ed., X., 118.	MONOCEROS, c. (Auct). pseudodon (Burrow, 1815).	Or. occidentales, Amer. Bor., Porto Praya (Sinclair), Panama (Kellett).
58.	*L. amplustre* (Martyn).	Univ. Conch., I., t. 3.	Buccinum amplustre (Martyn). aplustre (Martyn). Murex aplustre (Chemnitz).	I. Annaa, Ins. Ascension.
59.	*L. Belcheri* (Reeve).	Conch. Icon., IV., f. 22, 1847.		Cargados Garajos. Ind. Laccadiv Ins.
60.	*L. pictus* (Reeve).	Conch. Icon., IV., f. 19, 1847.		Ins. Viti.
61.	*L. Californicus* (A. Ad.).	Gen. I., 153, nom. nud.		California.
62.	*L. vexillulum* (Reeve).	Conch. System, Vol. II., p. 229, f. 1.		

IV. PERISTERNIA. [Mörch] Yoldi Cat. 99, 1852.

LATIBUS § PERISTERNIA [Mörch] Paetel Cat, 1887, etc.

63.	*P. despecta* (A. Adams).	Proc. Zool. Soc., 315, 1854.	China.
64.	*P. castanoleuca* (Tapp. Canefri). Beechey's Mag. Zool. t. 91, 1844.	Philberti (Recluz) nom. præocc. sp. fossilis. tessellate (Recluz).	Insulæ. Philippinenses: *e.g.*, I. Ticao & Panay
65.	*P. spinosa* (Martyn). Univ. Conch., t. 4, 1789.	Murex columbarium (Chem.).	Ins. Viti.
	β. *iostoma* (Nuttall). Küster C. Cab., p. 36, t. 9, f. 1, 2,	Turbinella fasciata (Sowb.).	
		Buccinum spinosum (Martyn)	California ?
66.	*P. gibba* (Pease).	Proc. Zool. Soc., p. 54, 1855.	Ins. Howland. (Pease).
67.	*P. violacea* (Reeve).	Conch. Icon., f. 59, 1847.	?
68.	*P. microstoma* (Küster).	Conch. Cab. III. t. 26 f. 8, 9. an. var., sqq. ?	?
69.	*P. Forskallii* (Tapp. Canefri), 26, f. 6 7.		Mare Erythræum.
70.	*P. nassatula* (Lamk.).	Hist. VII., 110.	Mare Erythr., (J. J. Walker, R.N.) Oc. Ind., Ins. Philipp. Nov. Guinea, Nov. Caledonia Paumotus. Ins. I. Annaa, Andaman, etc.
	β. *Deshayesii* (Kobelt).		Ins. Seychellenses, Amirantes, Mascarenes (Mus. Brit.).
	γ. *submassatula* (Sowerbie).		Nov. Caledonia.

44. *L. gibbulus* (Gmelin). Syst. Nat., 3557.	"Le Latire Orange." LATIRUS TYP. MONTFORT, 1810.		Australia.
45. *L. tumens* (Carpenter). Proc. Zool. Soc., 315, 1854.			America centr.
46. *L. cariniferus* (Lamk.). Hist., VII., 108.			Ins. Viti.
47. *L. distinctus* (A. Adams). Proc. Zool. Soc., 315, 1854.			Curaçoa I. Sinus Mexicanus (Dr. Epp.).
48. *L. armatus* (A. Ad.). Proc. Zool. Soc., 314, 1854.	trochlearis (Küster).		Goree, Sierra Leone, Africa occ., Ind. occid.
β. *Maderensis* (Watson). *c. f.* R. Boog Watson, Zool. Challenger Exped., XV., p. 243.	CHASCAX (Watson). propr. gen. Turbinella spinosa (Gray), Ann. and Mag. N. H. 1838, I. p. 28.		Madeira.
49. *L. rudis* (Reeve). Conch. Icon., IV., f. 51, 1847.			Ind. occidentales
50. *L. ceratus* (Gray). Zool., Beechey's Voyage, p. 114.			Ins. Gallapagos, Panama, Mazatpan (R. B. Hinds).
51. *L. tuberculatus* (Brod.). Proc. Zool. Soc., VII., 1833.			Ins. Gallapagos, Ind. occident.
52. *L. triserialis* (Lam.). Hist., VII., 10.			I. S. Vincent, Africa occident: Bahia, Brasilia.
β. *Hidalgoi* (Crosse). J. de Conch., XIII., p. 414, t. 14, f. 1.			
γ. *Stokesii* (Gray). Zool., Beechey's Voy., p. 114, 1839.			Porto Praya, C. de Verde Ins.
δ. *dubius* (Petit). J. de Conch., IV., p. 75, t. 2, f. 9, 10, 1853.			Fernando Noronha I. (Ridley), Ind. occident.
53. *L. ocellatus* (Gmelin). Syst. Nat., X., 748.			
β. *nigellus* (Chemnitz).	Fasiolaria cingulifera, Enc. meth., incultus (Gould)		Cedar Keys, Florida occ.:—ad Ind.: occident: Floridas.
54. *L. cinguliferus* (Lam.). Hist., VII., 108.	Murex nassa (Gmel). (pars.)		Fernando, Noronha I. (H. N. Ridley), St. Vincent I. (Mus. Brit.), Gambia, Senegal, et Ind. occidentales.
β. *Knorrii* (Desh.). Anim. Sans. Vert., IX., 391.	Turbinella castanea (Gray). fuscatus (Gmel).		Key West, Florida mer (J. C. Melvill, 1872). Honduras.
γ. *Brasilianus* (D'Orb.). Voy. Amer. mer. 449, t. 77.	angulatus (Kobelt).		Brasilia, Ins. occidentales.
δ. *angularis* (Reeve). C. Icon., IV., f. 49, 1847.			,,
ε. *Rüseanus* (Dunker). [Kobelt, 83].			,,
55. *L. leuconotalis* (Lam.). Hist., VII., 107.			Honduras.
	Buccinum smaragdulus (Linn).		
	,, rusticum (Gmelin).		

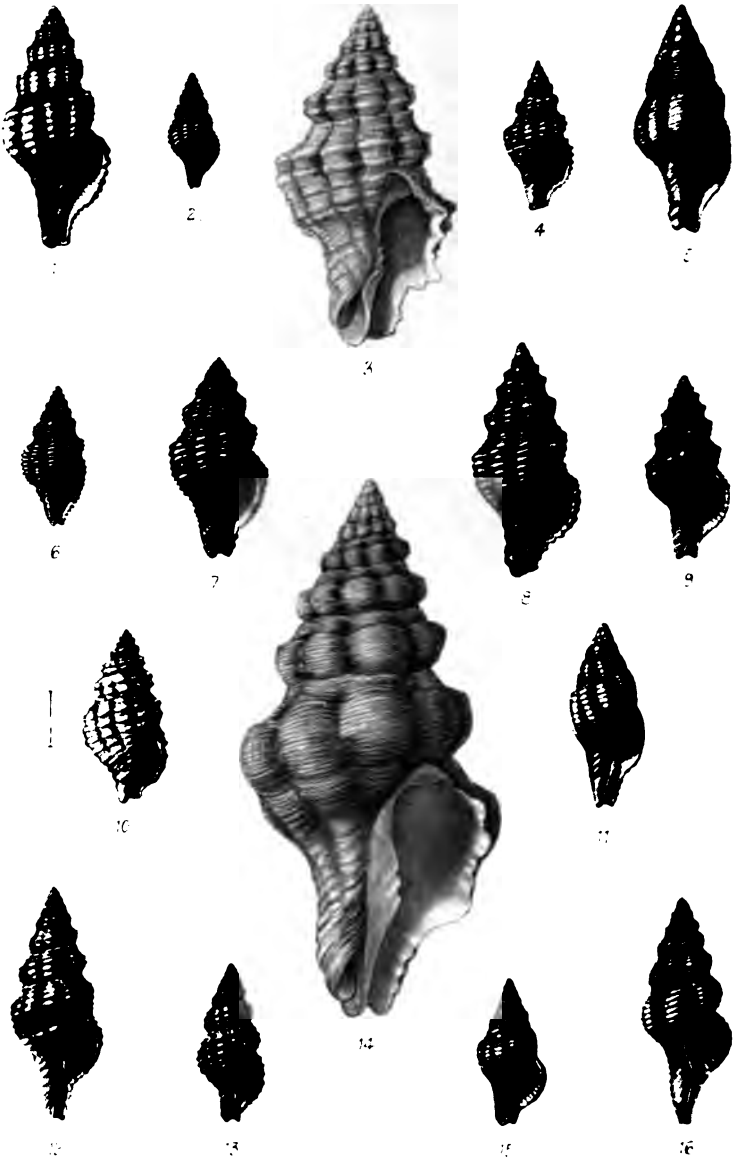
93.	*P. Caledonica* (Petit). J. de Conch., II., 367, t. 10, f. 6, 1851.		Nov. Caledonia.
94.	*P. Marquesana* (A. Adams). Proc. Zool. Soc., p. 315, 1854.		Ins. Marquesas.
95.	*P. retiaria* (Melvill), 1891.		Ins. Mauritius.
96.	*P. Carotiana* (Tapp. Canefri). J. de Conch., 1882, p. 31.	ustulata (Kobelt, non Reeve).	,,
	Soc. Mal. Belgique, 1880, XV., pl. 3, f. 15, 16.		
97.	*P. bicolor* (Kobelt). Küster C. Cab. 75, f. 18, f. 8, 9.		
98.	*P. Rollandi* (Bernardi and Crosse). J. de Conch., IX., 50, t. 1, f. 5.		Nov. Caledonia.
99.	*P. ustulata* (Reeve). Conch. Icon., IV., f. 62, 1847.	iricolor (Homb. and Jacq.).	N. Caledonia, Tongataboo, Ins. Viti, Mauritius, Ins. Salomon (Mus. Brit.), (Brazier).
100.	*P. concinna* (Tapp. Canefri). Ann. Soc. Mal. Belg., 1880, XV., pl. x., f. 10, 11.		Mauritius.
101.	*P. melanorhyncha* (Tapp. Canefri). J. de Conch., 1882, p. 35, fol. II., fig. 6, 7.		
102.	*P. Strangei* (A. Ad.). Proc. Zool. Soc., 316, 1854.		Levuka I., Fiji, (Challenger exped.). Sydney et. Port Jackson. Australia (Angas).
103.	*P. leucothea* (Melvill), 1891.		Natal.
104.	*P. sulcata* (Gray). Zool. Beechey's Voyage, 116.	scabrosa (Reeve).	Tongataboo I. Tahiti. ad. oc. fl. Brunei, Borneo, (Mus. Brit.)
	β. *crocea* (Gray), non Reeve, Zool. Beechey, 113.		
	γ. *gracilior* (Kobelt).		
105.	*P. chlorostoma* (Sowb.).	solida (Reeve). clathrata (Küster).	
	β. *Newcombii* (A. Ad.)	craticulata (Schubert).	Ins. Sandwich.
106.	*P. striata* (Gray). Zool. Beechey Voy., 114, 1839.	crocea (Reeve). chlorostoma (Nuttall). crenulata (Kiener).	Ins. Aru. Natal. Caroline Isles.
107.	*P. stigmataria* (A. Ad.) Proc. Zool. Soc., 313, 1854.	stigmaria (Pease).	I. Sandwich.
	β. *Samoensis* (Anton).		I. Samoa.
108.	*P. Selinæ* (Melvill), 1891.		I. Sandwich.
109.	*P. Australiensis* (Reeve). Conch. Icon., IV., f. 56, 1847.		P. Essington, Australia.
110.	*P. Iniuensis* (Melvill), 1891.		Iniue vel. Savage Ins. (W. W. Perry, Esq.).
		bucciniformis (Kiener). crenulata (Reeve).	
111.	*P. Wagneri* (Anton). Verzeich, 71, 1839.	craticulata (Wagner). tigrina vars (Hombr. and Jacquin).	Capul I., Philippinensis. Mauritius (Robillard).

71. *P. Lobbeckii* (Kobelt). Küster's Conch. Cab., 104, t. 20, f. 4, 5. — Ins. Pacificæ.
72. *P. elathrata* (Val.). Kiener, 46, t. 18, f. 4. — ?
73. *P. gemmata* (Reeve). Conch. Icon., IV. f. 5, 1847. — Oc. : Ind.
74. *P. lirata* (Pease). Am. J. Conch. IV., 152, 1868. gemmata (Reeve var.) — Ins. Marquesas.
75. *P. decorata* (A. Ad,). Proc. Zool. Soc., 316, 1854. — Nov. Zealandia (Mus. Brit.) Ins. Andaman. (Capt. W. Wilmer).
76. *P. Kobeltiana* (Tapp. Can.). Zealandica (A. Ad.)? — N. Zealandia? Mauritius.
77. *P. mannophora* (Melvill), 1891. — Madagascar.
78. *P. hilaris* (Melvill), 1891. — Mauritius.
79. *P. granulosa* (Pease). — Paumotus I.
80. *P. canthariformis* (Melvill), 1891. — Mauritius.
81. *P. cremnochione* (Melvill), 1891. — ,,
β. *photiformis* (Melv.), 1891. — ,,
82. *P. Smithiana* (Melvill, 1891. — ,, Aden.
83. *P. maculata* (Reeve). Conch. Icon., IV., f. 70, 1847. — ,,
84. *P. nana* (Reeve). Conch. Icon., IV., f. 67, 1847. — Java.
85. *P nassoides* (Reeve). Conch. Icon., IV., f. 71, 1847. — Ceylon, Ticao, I. Philippin. (Cuming).
86. *P. pulchella* (Reeve). Conch. Icon., IV., f. 65, 1847. — Zanzibar, Africa, Oc., N. Caledonia.
β. *neglecta* (A. Ad.). Proc. Zool. Soc., 314, 1854. — China.
γ. *sutoris* (Kuster). Conch., Cab. 106, t. 25, f. 10, 11.
87. *P. flavida* (A. Ad.). Proc. Zool. Soc., p. 314, 1854. — Latirus flavidus (A. Ad.)
88. *P. Mariei* (Crosse). I. de Conch., XVII., 177, t. 8, f. 2, 1869. — Nov. Caledonia.
89. *P. incarnata* (Desh.). Voy. Laborde, t. 65, f. 20, 22. — Ins. Philippinenses, Oc. Ind. Mare Erythræum). Ins. Sandwichenses, Ins. Andaman(Capt. W. Wilmer), Ceylon (E. W. H. Holdsworth), Swan R., Australia. (Mus. Brit.).
90. *P. infracincta* (Kobelt). Küster Conch. Cab. 92, t. 22, f. 16, 17.
91. *P. annulata* (Bolten). — ?
92. *P. Brasieri* (Angas). Proc. Zool. Soc., 171, t. 26, f. 4, 1877. — Red Bank Fl., Australia, Or (Angas).

93. *P. Caledonica* (Petit). J. de Conch., II., 367, t. 10, f. 6, 1851.			Nov. Caledonia.
94. *P. Marquesana* (A. Adams). Proc. Zool. Soc., p. 315, 1854.			Ins. Marquesas.
95. *P. retiaria* (Melvill), 1891.			Ins. Mauritius.
96. *P. Carotiana* (Tapp. Canefri). J. de Conch., 1882, p. 31.	ustulata (Kobelt, non Reeve). Soc. Mal. Belgique, 1880, XV., pl. 3, f. 15, 16.		,,
97. *P. bicolor* (Kobelt). Küster C. Cab. 75, f. 18, f. 8, 9.			
98. *P. Rollandi* (Bernardi and Crosse). J. de Conch., IX., 50, t. 1, f. 5.			Nov. Caledonia.
99. *P. ustulata* (Reeve). Conch. Icon., IV., f. 62, 1847.	iricolor (Homb. and Jacq.).		N. Caledonia, Tongataboo, Ins. Viti, Mauritius, Ins. Salomon (Mus. Brit.), (Brazier).
100. *P. concinna* (Tapp. Canefri). Ann. Soc. Mal. Belg., 1880, XV., pl. x., f. 10, 11.			Mauritius.
101. *P. melanorhyncha* (Tapp. Canefri). J. de Conch., 1882, p. 35, fol. II., fig. 6, 7.			
102. *P. Strangei* (A. Ad.). Proc. Zool. Soc., 316, 1854.			Levuka I., Fiji, (Challenger exped.). Sydney et. Port Jackson. Australia (Angas).
103. *P. leucothea* (Melvill), 1891.			Natal.
104. *P. sulcata* (Gray). Zool. Beechey's Voyage, 116.	scabrosa (Reeve).		Tongataboo I. Tahiti. ad. oc. fl. Brunei, Borneo, (Mus. Brit.)
β. *crocea* (Gray), non Reeve, Zool. Beechey, 113.			
γ. *gracilior* (Kobelt).			
105. *P. chlorostoma* (Sowb.).	solida (Reeve). clathrata (Küster).		
β. *Newcombii* (A. Ad.)	craticulata (Schubert).		Ins. Sandwich.
106. *P. striata* (Gray). Zool. Beechey Voy., 114, 1839.	crocea (Reeve). chlorostoma (Nuttall). crenulata (Kiener).		Ins. Aru. Natal. Caroline Isles.
107. *P. stigmataria* (A. Ad.) Proc. Zool. Soc., 313, 1854.	stigmaria (Pease).		I. Sandwich.
β. *Samoensis* (Anton).			I. Samoa.
108. *P. Selinæ* (Melvill), 1891.			I. Sandwich.
109. *P. Australiensis* (Reeve). Conch. Icon., IV., f. 56, 1847.			P. Essington, Australia.
110. *P. Iniuensis* (Melvill), 1891.			Iniue vel. Savage Ins. (W. W. Perry, Esq.).
	bucciniformis (Kiener). crenulata (Reeve).		
111. *P. Wagneri* (Anton). Verzeich, 71, 1839.	craticulata (Wagner). tigrina vars (Hombr. and Jacquin).		Capul I., Philippinensis. Mauritius (Robillard).

This list does not call for especial remark. Systematists despair of tracing most of the species described by Anton and Lesson, and two or three of Chemnitz are also impossible to fathom. It will be noticed that I have removed *Peristernia pulchra*, *Carolinæ*, and *Panluccia* to *Engina*, and it may be that all the species with crenulated denticulations on the outer lip, and tessellated arrangement of painting referred hitherto to *Peristernia*, may find their place there ultimately. *Latirus contemptus* (Ad.) is, according to Mr. E. A. Smith, a *Murex* allied to *M. badius* (Reeve). *Peristernia nodulosa* (A. Ad.), a white, chalky looking shell, with no sign of columellar plaits, is represented by two specimens in the British Museum, it is evidently a *Coralliophila*, and the *Turbinella Thersites* of Reeve, of which I have examined the unique specimen also in the British Museum, is a young specimen of some unknown species of *Fasciolaria*, or, perhaps, *Tudicla*.

(XVIII.) *Museums, &c., Consulted.*—The material on which I have mostly relied in giving this account and revision of the genus, is to be found either in the National Museum, S. Kensington, or my own collection. For the last twenty-four years I have endeavoured to make my series as perfect as I could, and with the result that over two-thirds of the species described are now contained therein. The National Collection has, excepting in a few cases, supplied the deficiencies, and I have several times carefully examined the large stores contained there, being befriended and aided in every possible way by Mr. Edgar A. Smith. There are a few mostly large, but fine species contained in the Museum, Owens College, Manchester, mainly from the Cholmondeley and Walton collections, and the Derby Museum, Liverpool has some good type shells. One or two of the more select species contained in the Leyden Museum, Holland, I have been able to examine



Mintern Bros. del. et lith. Mintern Bros. imp.

MEMOIRS AND PROCEEDINGS, MANCHESTER LIT AND PHIL SOC

through the kindness of Mr. M. M. Schepmann, and lastly, to the Rev. Alfred H. Cooke, of Cambridge, and Mr. H. M. Gwatkin, for valuable information concerning the dentition of the genus, I have already expressed my great indebtedness. A few of the shells described by M. Tapparone-Canefri, I have been sorry not to have been able to examine, in these cases I have had to draw my conclusions from plates and descriptions.

EXPLANATION OF PLATE.

1. *Peristernia annulata* (A. Ad.).
2. *Latirus Cayohuesonicus* (Sowb.).
3. *Do. distinctus* (A. Ad.).
4. *Peristernia mannophora* (Melvill).
5. *Do. flavida* (A. Ad.).
6. *Do. hilaris* (Melvill).
7. *Do. Selinæ* (Melvill).
8. *Do. Smithiana* (Melvill).
9. *Do. cremnochione* (Melvill).
10. *Do. Iniuensis* (Melvill).
11. *Latirus Eppi* (Melvill).
12. *Peristernia canthariformis* (Melvill).
13. *Do. retiaria* (Melvill and Schepmann).
14. *Latirus tumens* (Carpenter).
15. *Peristernia leucothea* (Melvill).
16. *Latirus formosior* (Melvill).

Ordinary Meeting, April 7th, 1891.

EDWARD SCHUNCK, Ph.D., F.R.S., F.C.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

A communication from Mr. PERCY F. KENDALL, F.G.S., the Secretary of the newly-formed North-West of England Boulder Committee, was read, in which it was stated that the Committee invited co-operation in the work of recording the fast-vanishing erratic blocks of the North-Western Counties of England. It is felt that, by concerted action, many priceless pieces of evidence regarding the Glacial Epoch can be rescued from destruction. The admirable work which has been done by the Yorkshire Committee furnishes an example of what can be accomplished. The Committee will operate in concert with the British Association Boulder Committee, and will report to that body; and, in addition, it is proposed to prepare a large scale map upon which all boulders, ice-scratched surfaces, and other evidence of glacial action, will be recorded. Descriptions of *all* exposures of glacial deposits, but more especially such as are of a temporary character, will be welcomed by the Committee, and arrangements made for their publication. The Committee has already at its command the nucleus of a collection of rock specimens, which will be available for comparison with boulders, and any donations of localized specimens from the Lake District, Galloway, the North-East of Ireland, or North Wales, would be valuable.

Mr. FARADAY exhibited and explained specially compiled tables in support of the conclusions in his paper

entitled "Thoughts on Credit Money and on the Function of the Precious Metals as Distributors of Wealth." The tables, forming part of the paper, showed the weight of gold and silver respectively exchangeable for one quarter of wheat in the London market at the end of March, 1891, and at the average prices in each of the preceding twenty years, and the production of gold and silver in each year of the same period. A discussion ensued, in the course of which Professor OSBORNE REYNOLDS suggested that the value of labour, as expressed in terms of gold, should be taken as a test, and Dr. SCHUNCK remarked that labour had become a more costly item in production than formerly. Mr. FARADAY contended that if labour were taken as a standard for testing the value of the precious metals, its increased efficiency, or intensity, must be treated as an increase of quantity in accordance with the argument of his paper.

Annual General Meeting, April 21st, 1891.

EDWARD SCHUNCK, Ph.D., F.R.S., F.C.S., in the Chair.

Mr. JOHN H. BUXTON, of Manchester, was elected an ordinary member.

The annual report of the Council was presented, and it was moved by Mr. WM. THOMSON, F.C.S., seconded by Mr. J. J. ASHWORTH, and resolved, "That the Annual Report be adopted and printed in the Society's *Memoirs and Proceedings*."

It was moved by Mr. WM. BROCKBANK, F.G.S., seconded by Mr. FRANCIS JONES, F.R.S.Ed., and resolved, "That the system of electing Associates of the Sections be continued during the ensuing session."

The following gentlemen were elected officers of the Society and members of the Council for the ensuing year:—

President—EDWARD SCHUNCK, Ph.D., F.R.S., F.C.S.

Vice-Presidents—WILLIAM CRAWFORD WILLIAMSON, LL.D., F.R.S., Foreign Member of the Royal Swedish Acad. Sc., and of the Royal Society of Göttingen, &c.; OSBORNE REYNOLDS, M.A., LL.D., F.R.S., &c.; ARTHUR SCHUSTER, Ph.D., F.R.S., F.R.A.S., &c.; JAMES BOTTOMLEY, B.A., D.Sc., F.C.S.

Secretaries—FREDERICK JAMES FARADAY, F.L.S., F.S.S.; REGINALD F. GWYTHER, M.A.

Treasurer—CHARLES BAILEY, F.L.S.

Librarian—FRANCIS NICHOLSON, F.Z.S.

Other Members of the Council—WILLIAM HENRY JOHNSON, B.Sc.; JAMES COSMO MELVILL, M.A., F.L.S.; HAROLD B. DIXON, M.A., F.R.S.; ALEXANDER HODGKINSON, M.B., B.Sc.; JOHN BOYD; JOHN F. W. TATHAM, M.A., M.D.

Ordinary Meeting, April 21st, 1891.

EDWARD SCHUNCK, Ph.D., F.R.S., F.C.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

It was announced by one of the Secretaries that Dr. Schunck had offered to present to the Society a bronze bust of the late Dr. R. ANGUS SMITH, and that the offer had been gratefully accepted by the Council; and it was moved by Mr. WILLIAM BROCKBANK, F.G.S., seconded by Mr. FRANCIS NICHOLSON, F.Z.S., and resolved, "That the members of the Society do give their hearty thanks to the PRESIDENT for his proposed memorial of their late distinguished member."

The following note, "On a New Method of estimating Chlorine in Organic Compounds," by Mr. ALBERT TAYLOR and Mr. GEORGE SHAW, of the Stockport Technical School, communicated by Mr. THOMAS KAY, was read by Mr. GEORGE SHAW:— "In the course of certain experiments made by us in the laboratory of the Stockport Technical School, with a view to the simplification of the existing methods of quantitatively determining the halogens in organic compounds, it was found that when such compounds as chloral hydrate were passed in the form of vapour, mixed with hydrogen, through a tube filled with broken quartz or other inert substances, and heated to redness, they were completely decomposed, the whole of the chlorine being given up in the form of hydrochloric acid, the carbon being deposited in the tube. It is proposed to continue the investigation over a wide range of com-

pounds, so as to ascertain if it might not be developed into a process of general applicability for the determination of chlorine, and, possibly, of the other halogens in organic bodies, and we hope at some future date to have the honour of bringing before the members of this Society the result of our continued experiments and researches."

Mr. JOHN BOYD communicated the third of Mr. P. CAMERON'S papers entitled "*Hymenoptera Orientalis.*"

Mr. WILLIAM BROCKBANK, F.L.S., F.G.S., read the second part of his paper "On a discovery of *Spirorbis* Limestones near Whitehaven," and also communicated a paper by Mr. J. W. DAVIS, F.G.S., &c., "On the discovery of a New Species of Fossil Fish (*Strepsodus Brockbanki*) in the Upper Coal Measures Limestones of Levenshulme."

A paper "On the action of Nitric Acid on Polyterpenes," communicated by Mr. W. W. H. GEE, B.Sc., F.C.S., was read by the author, Mr. H. L. TERRY, F.I.C. The author has studied the action of nitric acid of different strengths on the bodies known as polyterpenes, viz., caoutchouc, gutta percha, etc., and finds that although the ultimate action of the acid is to oxidise the substance into oxalic and carbonic acids, yet that a nitro-compound is formed as an intermediate product. This body, which is best prepared by allowing thin sheets of india rubber to stand in nitric acid, diluted with an equal volume of water, for some weeks, is a yellow amorphous powder. It exhibits the properties of a nitro-compound, and when heated to 105°C. decomposes suddenly, giving off nitric vapours, and leaving a mass of free carbon. It is partially soluble in alcohol, but quite insoluble in ether, chloroform, benzene, and carbon bisulphide. It is easily soluble in alkalies, forming a red solution, although this is not a case of hydrolysis, as the substance liberated from the solution by acids is insoluble in ether. No crystalline body has, as yet, been obtained for analysis, but the ultimate analysis of the yellow substance

gave the following figures, which point to its being a mixture of a nitro with an oxidised body :—

Carbon...	50·50 %
Hydrogen	6·13
Oxygen...	37·94
Nitrogen	5·43
	100·00

The nitrogen is too low and the oxygen much too high for such a body as $C_{20}H_{32}NO_5$. A similar substance has been obtained by acting on caoutchouc with fuming nitric acid in a freezing mixture, and also by the action of the higher order of nitrogen. The investigation is being continued.

On the occurrence of the Permians, Spirorbis Limestones, and Upper Coal Measures at Frizington Hall in the Whitehaven District. By William Brockbank, F.L.S., F.G.S.

(*Received March 10th and April 21st, 1891.*)

Professor HULL describes the Whitehaven Coal Field in three divisions. (1) Upper Series: Purplish grey sandstones of Whitehaven. (2) Middle Series: Developed at Cleator Moor, where seven workable seams occur. (3) Lower Series: Containing four or five inferior seams. He adds that 'It has been a matter of some dispute whether the Whitehaven Sandstones should be classed as Permian or Coal Measures.' The Middle Series are now being worked at Cleator Moor, the measures being cut off by the Weddiker Hall fault. To prove the strata beyond this fault a bore hole is being put down near Frizington Hall, in the expectation of finding the same strata to the north-east as those now being worked on the westerly side of the fault. The bore-hole commenced in surface clays, &c., conglomerate being reached at 22ft.—it was 20ft. thick. This was succeeded by red and mottled shales and sandstones for 50ft. when limestone was passed through. Cores representing these beds have not yet reached me, but I should expect to find them Permian and Upper Coal Measures. This, I hope, will shortly be cleared up. The reddish limestone occurred at 114ft. 10in. from the surface, and was 3ft. 9in. thick. It was followed by grey sandstones, conglomerates, and red shales, for 148ft. 8in., when a bed of white limestone was reached, 1ft. thick, at a total depth of 263ft. 6in. from the surface.

These limestones were not expected, and it was feared that the coal-bearing strata had been passed, and that here were the lower carboniferous limestones, such as occurred at Aldby and Hensingham, in the immediate neighbourhood; and the bore-hole was stopped accordingly. At this point of the operations samples of the limestones were forwarded to me, and I at once found them to be *Spirorbis* limestones, such as have recently been found at Levenshulme in the Upper Coal Measures, just below the Permian strata. This was reported to my Whitehaven friends on November 18th, 1890. I stated in my letter that I believed the upper portion of the section to be Permian, and the two limestones to be *Spirorbis* limestones of the Upper Coal Measures, and I advised that the boring should be proceeded with, as coal would probably be reached at a moderate depth. This course was adopted, and coal was reached at a depth of 297ft. 8in., and again at 317ft and 407ft, all thin seams, but in true Upper Coal Measures. At 477ft. 10in. a very hard grit was reached, at 542ft. red conglomerate, and the bore-hole is now stopped in conglomerates and hard sandstones at 573ft. 3in., the bed being a fine hard grit like the first grit 100ft. above it. These I take to be the Whitehaven sandstones.

Now there are some very interesting points arising out of the above recital, which I wish to lay before the Society very briefly, reserving a full description for a future paper, when the boring is completed and the cores of the upper portion reach me. Cores of the lowest borings are now exhibited to show their resemblance to the Whitehaven sandstones. The section undoubtedly represents the Upper Coal Measure series; (probably) commencing with the Permians, and continuing down to the sandstones and conglomerates, which I take to be the same as the Whitehaven sandstones which Prof. Sedgwick

and Mr. Binney held it to be Permian. If I am correct in my identification they thus become Middle Coal Measure Sandstones beyond doubt, as they are 214 feet under the Lowest *Spirorbis* limestone. Mr. Binney dealt with this subject in a paper read before the Society, October 20th, 1853, and printed in the *Memoirs* 2nd Series, Vol. 2, p. 353. The Whitehaven sandstone he says is about 140ft. thick, and he considered it a Coal Measures rock many years ago. Then he had only examined the upper portion of it, and had not seen the lower parts, which for 30ft. are of a conglomerate character, containing white quartz pebbles the size of a common bean, and much peroxide of iron, and decomposed felspar, and not to be distinguished from Millstone Grit. It also contains traces of volcanic ash (p. 371). He sums up the question thus:—"If not classed as Permian it must be upper and unconformable Coal Measures. The chief reason which has induced me to remove them from the Carboniferous strata is the conglomerate character of the lower part of the sandstone, which, as previously stated, is more like Millstone Grit than an Upper Coal Measure rock. For the present, it appears to me desirable to retain it, as Professor Sedgwick first designated it, by the name of Lower Red Sandstone, or my name of Lower Permian." This conglomerate, which is a portion of the Whitehaven sandstone, is so singular a rock and so strongly marked, as to be almost unmistakeable.

The Whitehaven sandstone occurs for a considerable distance along the coast, all the strata above it having been denuded—so that this is the first time of its recorded occurrence in its true position, so far as I am aware. The *Spirorbis* limestone has not been previously found in the Whitehaven coal field, though it occurs at Cannobie, just over the Scottish border. Its discovery is, therefore, of special interest. The first bed is 3ft. 9in. thick, of a pinkish colour, and has the following constituents:—

Silica	2·8
Alumina with Iron	1·2
Carbonate of Magnesia...	4·2
Do. Lime	91·8
	100·00

Two examples were sent, and in each of them *Spirorbis* was to be found with a lens. I had thin sections cut, which showed their structure to be very similar to that of the Levenshulme limestones. They take the same marble polish, and are mottled. Under the microscope the reddish colour is seen to be produced by numerous red crystals, probably hematite stained. The sections now exhibited are full of *Spirorbis* and *Entomostraca*—probably Ostracods of the *Carbonia* groups—and there is one small shell of a brachiopod. The ostracods are frequently in pairs and very perfect—but there are many detached and broken shells. The white limestone which occurs at the greater depth is a very beautiful object under the microscope. Veins run across the section in roughly parallel lines, and of these there are two distinct sets, the later series being darker coloured and cutting through the lighter veins. The *Spirorbis* and Ostracods are abundant, and some of them beautifully perfect. The veins cut through these fossils, which have evidently been broken through long after they were calcified. It will thus be seen that the limestones exactly resemble those from Levenshulme, which were recently exhibited to the Society, and the whole series of strata resembled those in which the *Spirorbis* limestones occurred. There can, therefore, be no doubt that they belong to the uppermost of the Upper Coal Measures which have not previously been recognised in the West Cumberland coal field.

At the time of communicating the foregoing to the Society (March 10th), the cores from the Diamond rock

boring at Frizington Hall, from the surface down to the *Spirorbis* Limestone, at 114′ 10″, had not reached me; but I assumed that they would prove to be Permian and Upper Coal Measures. I have since that date visited the spot, and carefully inspected the whole of the cores, which are preserved at the colliery. As this section will probably be considered a typical one for the Permians and Upper Coal Measures in West Cumberland, a full account of the strata thus proved will be appended to this communication. It agrees in a remarkable way with the section recently exposed in the railway cutting at Levenshulme, a full account of which has recently been laid before the Society. But for the experiences gained at Levenshulme, the Frizington Hall section would probably not have been understood.

In the bore hole at Frizington Hall, after passing through the surface clays for 22 feet, a mass described as "Conglomerate" was met with. This proves to have been the *Breccia*, which occurs generally at the base of the Permians. These Permian breccias are always made up of angular fragments of the rocks which occurred in the immediate neighbourhood, and at Frizington the volcanic, or Borrowdale series of the Ennerdale district, and the Skiddaw slate rocks of Dent, hem in the coal field. The breccia at Frizington is made up of these, cemented together with hematite. Owing to the extremely hard nature of the fragments, the cores brought up by the boring tools were in a fragmentary condition, no perfect cores being obtainable. I therefore made a careful examination of the *débris*, which represented this 20 feet of "conglomerate," and selected some excellent samples therefrom. Many limestone fragments were intermixed with these older rocks, and I have had slices prepared from them for the microscope. To my great surprise I found these limestones, which were thus included in the breccia, contained fragments of fossils, identical with those found in the *Spirorbis*

limestones which occurred in the bore hole at 114 feet and 263 feet depth, and it was probably the lower limestone of the two which furnished the fragments. The Permian sea had evidently broken up the outcrop of this limestone, and it became thus curiously intermixed with the Silurian slates and porphyries in the Permian breccia. Fragments of *Ostracoda* shells and *Spirorbis* are clearly visible under the microscope.

The remainder of the borings between the Permian breccia and the *Spirorbis* limestone reminded one of similar strata at Levenshulme. There were the red and mottled shales, the soft red micaceous sandstones, the laminated red and grey shales, and the brecciated red marls, everywhere hematite stained—just as we found those at Slade Lane,—and the small green "fish-eye" mottlings were also present, but not to so marked an extent. Just beyond the Frizington Hall Estate there is a deep ravine through which Dub Beck runs, and I felt sure the outcrop of this breccia might be found there. It was about one-third of a mile from the bore hole. We, therefore, examined this valley, and soon found the breccia in the brook course, with the St. Bees sandstone above it, forming a bold escarpment to the north-east. A little further on, at Mill Yeat, we found that hematite ore had been worked as a surface deposit many years ago, just overlain by the Permian breccia, thus confirming most precisely the whole position. I had a section cut for the microscope from the breccia, taken at the outcrop near Mill Yeat, and to my great surprise again found it fossiliferous. The limestone fragments in it contain the Fifeshire variety of the *Spirorbis (S. Helicites)*, and there is a most beautiful spiral shell of a gasteropod, which I should have taken to be a *Luxonema* but for its tiny size. It is probably *Turbo* or *Turritella*. I have no doubt that this Frizington Hall section will furnish the explanation of a good deal of the geology of the eastern portion of the

Whitehaven coalfield, which has not hitherto been correctly described, but this aspect of the question I leave for a future paper. I found the same breccia occurring in a bore hole now being made at Messrs. Ainsworth's mines at Winder to the last. I also traced it for above a mile in the neighbourhood of Gosforth, where it is not shown on the Geological Survey Map. It is a most important matter, as wherever the Permian breccia occurs, there is a probability, in this Whitehaven district, of the occurrence of hematite ore beneath it. In the Gosforth district it holds out a promise of a workable coal field between that village and the sea.

SECTION AT FRIZINGTON HALL, CLEATOR MOOR,

By Bore Hole made by Vivian Boring Co., 1890-1.

Thickness of Strata. Feet.		Depth from Surface. Feet.
22·0	Surface Clays	22·0
20·0	Permian breccia made up of angular fragments of Silurian and Volcanic rocks, and Limestone cemented with Hematite. The Limestones contained fossils similar to those seen in the *Spirorbis* Limestones	42·0
9·4	Red Shales	51·4
7·0	Mottled Shales	58·4
9·2	Soft purple Sandstone with Mica specs ...	67·6
4·0	Mottled, Purple and Green Shales	71·6
12·8	Rotten Red Shales	84·2
26·11	Red Shales	111·1
3·9	Reddish Limestone—with *Spirorbis* and *Ostracoda* (Upper Coal Measures) ...	114·10
10·8	Purple Sandy Shales	125·6
11·0	Conglomerate—like the Brecciated Marls at Slade Lane, Levenshulme, with Limestone Pebbles and cherty fragments, cemented with Hematite ...	136·6
6·0	Grey and Pink Mottled Shaley Sandstones	142·6

Thickness of Strata. Feet.		Depth from Surface. Feet.
39·1	Shaley Conglomerate, of very dark Purple laminated Marls, with fine Mica... ...	181·7
6·0	Red Shales	187·7
5·6	Red and Grey Sandstone—fine grained coal measure sandstone with fine white mica	193·1
20·3	Grey Sandstone	213·4
17·0	Grey Sandstone. very jointy	230·4
14·11	Grey Sandstone	245·3
5·9	Red Shale...	251·0
11·6	No particulars of these beds	262·6
1·0	White Limestone with *Spirorbis* and *Ostracoda*	263·6
2·6	Red Sandy Shales	266·0
16·0	Mottled Shales—Dark Chocolate Purple with brecciated fragments of pale Greenish Limestone	282·0
5·0	Dark Purple Brecciated Marls...	287·0
1·6	Grey Sparry Sandstones—the joints with Carbonate of Lime, Spar and Hematite	288·6
1·10	Red and Grey Shales	290·4
7·0	Blue Metal with Red Stripes (Bookleaf Marls with calcareous partings)	297·4
0·4	Brassey Coal	297·8
2·9	Blue Metal with Red Stripes and plant remains, probably *Stigmariæ*—strap-like leaves	300·5
1·0	Grey Sandstones	301·5
10·10	Blue Metal with Red Stripes and plant remains as above...	312·3
3·10	Blue Metal—Fire Clay	316·1
1·0	Coal	317·1
11·0	Blue Metal	328·1
5·0	Fire Clay (Grey)	333·1
5·8	Red Shale, with small bands of Blue Metal	338·8
15·4	Indurated Greenish Marl...	354·1
7·11	Fire Clay	362·0

Thickness of Strata. Feet.		Depth from Surface. Feet.
33·2	Blue Metal	395·2
2·0	Fire Clay	397·2
7·1	Blue Metal	404·3
1·9	Soft Blue Metal	406·0
1·3	Coal...	407·3
7·6	Soft Blue Metal	414·9
3·2	Sandy Blue Metal	417·11
1·0	Broken Red Shale	418·11
6·11	Red Sandstone	425·10
5·0	Red Shale...	430·10
7·2	Red Grey Shales	438·0
6·4	Red Grey Sandstones, very jointy	444·4
6·0	Red Sandy Shales	450·4
0·6	Reddish Coarse Grained Sandstone ...	450·10
9·0	Reddish Grey Coarse Grained Sandstone	459·10
0·10	Reddish Fine Grained Sandstone	460·8
17·2	Very hard Fine Grit Sandstones (Whitehaven Sandstones 1st bed), with beds of soft Purple Shales	477·10
15·2	Mottled Sandy Shales	493·0
5·1	Red Shale, with small beds of Sandstone.	498·1
5·2	Red Shale, with beds of Sandstone ...	503·3
5·8	Mottled Shale	508·11
21·7	Purplish Fine Grained Sandstone, very jointy	530·6
11·10	Conglomerate. Dark Purple Hematite, stained with large Quartz Pebbles, and angular white fragments of Silica, or possibly Volcanic Ash, as described by Mr. Binney (Whitehaven Sandstone)...	542·4
8·6	Red Grey Sandstone...	550·10
3·0	Reddish Grey Sandstone	553·10
7·0	Dark Smooth Purple Shales	560·10
7·2	Reddish Grey Sandstone	568·0
5·3	Reddish Grey Sandstone like the first grit at 447·10, with beds of Shale	573·3

On the discovery of a new species of Fossil Fish (Strepsodus Brockbanki) in the Upper Coal Measures Limestone of Levenshulme, No. 6 Group, from the Railway Cutting at Levenshulme, near Manchester. By James W. Davis, F.G.S., &c. Communicated by William Brockbank, F.L.S., F.G.S.

(Received April 21st, 1891.)

A number of fragmentary remains have been found in the hard Limestone, which it is proposed to notice in detail.

No. 1 exhibits the section of a tooth split in the matrix longitudinally. The tooth is apparently exhibited from the apex to the base, and has a length of 0·015 m.; of this the crown of the tooth occupies 0·010 m. It has a thick external coating of dentine, and the internal cavity is moderately large, wide at the base of the crown, diminishing towards the point. The root, as exposed in this specimen, has a width of 0·009 m.; and appears to have been of a more or less spongey character, with distinct lacunæ interspersed in its substance. The under surface of the root exhibits a peculiar notch or incision of the surface which is not ordinarily observed in teeth of this species.

No. 2 exhibits a portion of one of the large teeth; the base is broken away, and the point is hidden in the matrix. The surface of the tooth is exhibited, and is the ordinary form exhibited by *Strepsodus*, the twist in the upper part being clearly indicated. The concave inner surface is covered with deeply incised striations, which become gradually effaced towards the convex outer surface, which is quite smooth.

No. 3 exhibits a broken portion of another tooth similar to the last, but not so well preserved.

No. 4 is a more important example. It consists of a portion of one of the jaws, exhibiting a section from the

alveolar surface to the base, which is 0·010 m. in diameter; in the opposite direction the diameter is equal to half the height. The basal, or under surface of the jaw is exhibited, and from its peculiar curvature appears to indicate that the part preserved is the anterior portion of the right ramus of the lower jaw, with the symphisial extremity slightly exposed. The surface of the bone is smooth, with the exception of a few moderately large punctures. Attached to the upper surface of the jaw is a small tooth, probably intermediate between the large lamiary tooth, which has a length of 0·004 m. It has similar characters to the larger ones, and its surface is distinctly striated. In the matrix adjoining there is the impression of a second similar small tooth.

No. 5. Large bone exhibiting internal structure. The external surface, where exposed, is of the same character as the exposed part of the jaw in No. 4, and in other respects it may be possible that this bone is a larger jaw of the same species, but there are no distinct indications of teeth. The part preserved is about 0·05 m. in length, and 0·022 m. in breath.

No. 6. Dermal bones, probably from the cranium.

No. 7 is a bone similar to No. 5, broken into four separate pieces, but exhibiting no well-defined character.

Nos. 8, 9, and 10 are apparently more or less fragmentary remains of small ribs, which, being found associated in the same bed with the specimens already named, may naturally be inferred to have belonged to the same species, if not to the same fish. The best preserved specimen (No. 8) is 0·03 m. in length, and is 0·002 m. in diameter; both ends are broken off. The portion preserved exhibits a gentle curvature.

No. 11 is a specimen of a rib which is probably complete, and is 0·06 m. in length, and is about the same diameter as the others. It has a bold curvature, the distal

extremity is buried in the matrix, but its extent is indicated by the red colour of the fossil in the grey matrix, a character which is exhibited in all these remains. The proximal end of the rib is more or less expanded, apparently for attachment to the vertebral column.

Though the remains described are fragmentary, quite sufficient evidence is afforded of the generic identity of the fish remains, and there can be no hesitation in placing them in the genus *Strepsodus*; with respect to the specific determination, however, the position is not so well defined. The teeth differ from *Strepsodus sauroides*, Young,* in the greater breadth in proportion to the length; the surface striation is similar in the two, with the exceptions that in this species the striæ are larger, and there is no evidence of bifurcation, and whereas in *S. sauroides*, the base of the crown is ovoid, and laterally compressed, and the apex twice bent nearly at right angles, in this species the base of the crown is circular, and the point is not twisted to the same extent. A second species has been described by Dr. Traquair, from the limestone of Borough Lee, near Edinburgh, under the name of *Strepsodus striatulus*.† It is a smaller species than *S. sauroides*, is compressed, oval in transverse section, incurved, hardly geniculated at the apex, the base having relatively coarse plications. The shaft of the tooth is ornamented with very delicate, closely placed, sub-parallel raised striæ. The absence of a figure of this species renders a comparison somewhat difficult, but the characters of the teeth are readily distinguished. I prefer, therefore, to regard this species as hitherto undescribed, and suggest the *nomen triviale*, *Strepsodus Brockbanki*, derived from the name of its discoverer, who has done so much for the elucidation of the fauna, as well as the general stratigraphical arrangement of these beds, the highest in the carboniferous series hitherto described.

* *Quart. Journ. Geol. Soc.*, Vol. xxii, p. 602, woodcut 3, 1866.
† *Geol. Mag.*, Sec. II., Vol. ix., p. 544, 1882.

[*Microscopical and Natural History Section.*]

Annual Meeting, April 27th, 1891.

Mr. J. COSMO MELVILL, M.A., F.L.S., in the Chair.

There were exhibited by Mr. H. HYDE a dried specimen of *Sigarctus* enclosing the shell, and a *Murex* covered by the ova of some mollusc; by Mr. E. PYEMONT COLLETT, F.E.S., *Pleisthenes scutellatus* (Dist.), recently described as new to science, from S.W. New Guinea; also nineteen species of Ants' nest beetles with their hosts.

Mr. P. CAMERON, F.E.S., read Part III. of his "*Hymenoptera Orientalis.*"

The Secretary read the thirty-third annual report of the Council of the Section, and the Treasurer submitted the annual balance sheet and statement of accounts.

On the motion of Mr. CHARLES BAILEY, F.L.S., seconded by Mr. T. ROGERS, the report of the Council and the accounts were approved.

The following gentlemen were elected officers and members of the Council for the ensuing session:—

President:—ALEX. HODGKINSON, M.B., B.Sc.

Vice-Presidents:—CHAS. BAILEY, F.L.S., J. COSMO MELVILL, M.A., F.L.S., W. C. WILLIAMSON, LL.D., F.R.S.

Treasurer:—MARK STIRRUP, F.G.S.

Secretary:—JOHN BOYD.

Other Members of the Council:—P. CAMERON, F.E.S., E. PYEMONT COLLETT, F.E.S., H. C. CHADWICK, R. E. CUNLIFFE, R. D. DARBISHIRE, B.A., F.G.S., F. NICHOLSON, F.Z.S., THOMAS ROGERS, THEODORE SINGTON.

Hymenoptera Orientalis; or Contributions to a knowledge of the Hymenoptera of the Oriental Zoological Region. By P. Cameron. Communicated by John Boyd.

Received May 1st, 1891.

PART III.

POMPILIDÆ.

I have experienced considerable difficulty in identifying the numerous species of this large family, described by the late Mr. F. Smith, of the British Museum. This is more particularly the case with the black species, and with those related to *Salius flavus*, Fab. These latter I find to be especially puzzling, from the fact that the same type of colouration is found in two of the sections of *Salius* and in *Pompilius*. I have myself, with the aid of numerous examples, come to definite conclusions as to the limits of the species with those of the *flavus*-colouration; but I am in so much difficulty about the nomenclature, that I have decided to leave them over until I have had an opportunity of examining Smith's types. I am the more inclined to do so from finding in Mr. Rothney's collection a *Pompilus*, and a *Salius* named *dorsalis*, Lep., by Mr. Smith.

As regards the genera, I have adopted them as defined by Kohl in his paper "Die Guttungen der Pompiliden" in *Verh. z.-b. Ges. Wien*, 1884.

The species of *Pompilidæ*, as a rule, store their nests with spiders; but very little is known about the habits of the Indian species. Major Bingham describes the nest of *Pompilus bracatus* as a "burrow in the ground at the foot of a large fern," and he observed it provisioning its nest

with a small cockroach. *P. Greeni* was reared by Mr. Green from a cocoon in what had evidently been a large spider's nest between two leaves; and he surmised that the grub had been feeding on the spider's eggs.

CEROPALES.

Ceropales, Latreille, *Prec. caract. gen. Ins.* 1796, p. 123; Kohl, *Verh. z.-b. Ges. Wien*, 1884, p. 51.

1. CEROPALES FUSCIPENNIS.

Ceropales fucipennis, Smith, *Cat. Hym. Ins.*, iii., p. 179.[1]

Hab. India.[1]

This agrees with *Orientalis* closely in the colouration of the head, thorax, and legs, but differs in having the abdomen ferruginous, black at the base.

2. CEROPALES ORIENTALIS, *sp. nov.* (Pl. III. f. 4).

Black, pruinose, the abdomen with a bluish tinge; the clypeus, except a triangular black mark in the centre, the mandibles except at the apex, the inner orbits broadly to the ocelli, the outer orbits from near the top of the eyes to the mandibles, a broad line on the pronotum, narrowly incised in the middle, and broadly at the sides in front, two elongate marks on the scutellum, a small mark on the propleuræ, a large one immediately over the middle coxæ; the fore coxæ broadly beneath, the middle coxæ with a small and a large mark beneath and two broad bands on the base of the second abdominal segment, clear whitish-yellow; the trochanters, femora, tibiæ, and tarsi red; the spurs and a line on the four hinder tibiæ yellow; the middle tibiæ entirely, the hinder black and yellow behind; the tarsal joints black at the apices, the anterior with the joints whitish at the base. Eyes slightly curved above, reaching to the base of the mandibles, diverging slightly beneath. Ocelli in a curve, the vertex depressed in

front of them, and a minute furrow runs down from them to the antennæ; the hinder separated by a somewhat greater distance from each other than they are from the eyes. Clypeus at the apex margined, forming a rounded curve. Antennæ stout, brownish beneath, the joints curved beneath; the third joint a little shorter than the fourth. Pronotum obliquely rounded at the sides. Metanotum densely covered with long whitish hairs; median segment with a bluish tinge; and a gradually-rounded slope; alutaceous, sparsely covered with long white hairs. There is a longitudinal furrow in the centre of the mesopleuræ. Abdomen sessile, granular, the basal segment covered thickly with stout white depressed hair, the rest of the abdomen pruinose. Legs thickly pruinose; the tibiæ sparcely spined; the long spur of the hind tibiæ fully two-thirds of the length of the metatarsus. Wings iridescent, hyaline at the base; from the basal nervure suffused with dark fuscous, darkest at the apex; the second cubital cellule at the top and bottom a little longer than the third; the nervures blackish.

Length 10 mm.

Hab. Barrackpore (*Rothney*).

4. CEROPALES CLARIPENNIS, *sp. nov.*

Black, shining, the mandibles, clypeus, face, orbits, except narrowly interrupted at the top; a line on the pronotum behind, the angles in front, a broad line at the apex of the mesonotum, a line on the scutellum, the metanotum, a narrow line down the middle of median segment; the propleuræ beneath, a broad oblique band on the mesopleuræ above and two smaller ones on the lower half, and two large marks on the metapleuræ, clear yellow. Abdomen ferruginous, the extreme base black. Legs reddish; the fore coxæ yellow, with a black mark behind; the four hinder coxæ black, yellow and red beneath, the tarsi black; the

spurs pale, the hinder about two-thirds of the length of the metatarsus. Wings clear hyaline, the second cellule half the length of the third above and beneath; the first recurrent nervure received slightly past, the second slightly in front of the middle of the cellules. Antennæ moderately thick; brownish beneath at the base; the third and fourth joints subequal. Eyes with a distinct curve at the top, distinctly converging at the apex; they being there separated by a little more than half the length they are at the top. Clypeus with the sides oblique, the apex transverse. Ocelli in a triangle, separated from the eyes by twice the length they are from each other. Pronotum semi-transverse behind, quadrate; the sides at the base projecting into triangular teeth. Mesonotum flattish, with two longitudinal furrows; the furrow on the mesopluræ narrow; metanotum gibbous; median segment with a gradual slope. Except on the median segment the body is almost glabrous.

Length, 8—9 millim.

Hab. Poona (*Wroughton*).

5. CEROPALES FLAVOPICTA.

Ceropales flavopicta, Smith, *Cat. Hym. Ins.* III., p. 178, 5[1].

Hab. India.

6. CEROPALES ORNATA.

Ceropales ornata, Smith, *Cat. Hym. Ins.* III., p. 179[1].

Hab. India.

7. CEROPALES ANNULITARSIS, *sp. nov.*

Yellow, a stripe across the vertex behind the eyes, a broad one leading down from it on the front, with a small yellow mark on its centre, a broad band in front of the pronotum, from which an oblique one runs up the pleuræ, the mesonotum, except along the sides, and a large squarish mark in the centre, this latter having a large black triangular

mark in the centre, the mesosternum, a large oblique mark on the base of the mesopleuræ, the base of the scutellum and the metanotum, black; the greater part of the meso- and meta- pleuræ and the median segment, reddish. Abdomen yellow; the first segment black at base and apex, the centre reddish; the second segment black and red at the apex; the third broadly black: the fourth black at the apex, the black in the middle being continued to the base of the segment; the fifth black at the base, the black being continued in the middle to the apex; the ventral segments broadly black. Legs ferruginous; the coxæ yellow and red; the trochanters blackish; the apex of the hinder tibiæ and of the four hinder tarsal joints black. Wings yellowish hyaline; the apex of both wings infuscated; the second cellule at the top and bottom longer than the third; the second and third transverse cubital nervures elbowed at the middle, thus narrowiug the second cubital cellule at the top; the first recurrent nervure is received in the apical third, the second a little before the middle. Antennæ ferruginous, longish; the joints curved; the third and fourth joints sub-equal. Apex of clypeus bluntly rounded; the sides rounded. Head, pronotum, and median segments bearing long white hair. ♂.

Long. 14 mm.

Hab. Poona (*Wroughton*).

How far the ferruginous colour is natural or discoloured by cyanide of potassium, I can't well make out. Certainly some parts of the body are so discoloured.

MACROMERIS, *Lep.*

Lepeletier de Saint-Fargeau, *Guér., Mag. Zool.*, XIV, pl. 29, 1831; Kohl, *l. c.* 41.

1. MACROMERIS VIOLACEA, Lep.

Lep., *Nat. Hist. d. Ins. Hym.* III., 463.

A common Indian species.

Hab. Barrackpore, Poona, Madras, Myssoure, China, Malacca, Borneo, Java, Gilolo, New Guinea, Celebes, Key, Aru, Floris.

2. M. SPLENDIDA, Lep.
Lep. *l. c.* 463[1].
Hab. Java[1].

3. M. ARGENTIFEROUS, Smith.
Smith, *Jour. Linn. Soc.* II., 97[1].
Hab. Borneo, Malacca, Singapore, Java[1].
In *Jour. Linn. Soc.*, 1867, p. 556, only Borneo is given as a habitat.

PSEUDAGENIA, *Kohl.*

Verh. z-b. Ges. Wien, 1884, 38 = *Agenia.* Dbm. non Schiödte, which = *Pogonius*, Dbm.

The basal nervure is said by Kohl to be interstitial; but this is not the case with many of our species.

1. PSEUDAGENIA ÆGINA, Smith, *Proc. Linn. Soc.* II, 94, 9.
Hab. Borneo.

2. P. ALARIS, Saussure, *Hym. d. Novara Reise*, 52[1].
Hab. Ceylon.[1]

3. P. ARIEL, Cam., *postea.*
Hab. Barrackpore *(Rothney).*

4. P. ATALANTA, Smith, *Proc. Linn. Soc.* II., 94, 8[1].
Hab. Borneo, Singapore, Malacca, Bachian, Celebes[1].

5. P. BIPENNIS, Saussure, *Hym. d. Novara Reise*, 52[1].
Hab. Ceylon[1].

6. P. BLANDA, Guérin, *Voy. d. Coq.* II., 260; Smith, *Proc. Linn. Soc.* II., 94, 7.
Hab. India, Malacca, Borneo, Celebes, Ceram, Key, Flores[1].

7. P. CÆRULEA, Smith, *Cat. Hym.*, III., 147, 141.[1]
Hab. India.[1]

8. P. CELAENO, Smith, *Proc. Linn. Soc.*, II., 96, 15.[1]
Hab. Singapore.[1]

9. P. CONCOLOR, Saussure, *Hym. d. Novara Reise*, 5, 4.[1]
Hab. Ceylon.[1]

10. P. DAPHNE, Smith, *Proc. Linn. Soc.*, II., 95, 10.[1]
Hab. Borneo.[1]

11. P. FLAVOPICTA, Smith, *lc.*, 96, 13.[1]
Hab. Singapore.[1]

12. P. FESTINATA, Smith, *Trans. Ent. Soc.*, 1875, 37.
Hab. Barackpore (*Rothney*).

13. P. FRAUNFELDIANA, Saussure, *Hym. d. Novara Reise*, 53,[1] f. 35.
Hab. Java, Batavia.[1]

14. P. HIPPOLYTE, Smith, *Proc. Linn. Soc.*, II., 96, 14.[1]
Hab. Singapore.[1]

15. P. INSULARIS, Saussure, *Hym. d. Novara Reise*, 55.
Hab. Ceylon.

16. P. LAVERNA, Smith, *Proc. Linn. Soc.*, II., 95, 1.[1]
Hab. Borneo.

17. P. MACULATA, Tashenberg, *Zeits. f. Gess. Wissen.*, 45, 1.
Hab. Java.

18. P. MELAMPUS, Smith, *Proc. Linn Soc.* II., 95, 12[1].
Hab. Borneo.[1]

19. P. MICROMEGAS, Saussure, *Hym. d. Novara Reise*, 51, *fs.* 35 *a-b.*
Hab. Ceylon.[1]

20. P. MUTABILIS, Sm.,
Agenia mutabilis, Smith, *Trans. Linn. Soc.* VII. 186.[1]
Hab. Mainpuri, North-West Provinces.

21. P. TINCTA, Smith, *Cat. Hym.* III. 145, 152.[1]
Hab. India.[1]

22. P. VARIPES, Dahlbom, *Hym. Eur.* I. 455, 7.[1]
Hab. India.

23. P. NANA, Saussure, *Hym. d. Novara Reise*, 55.[1]
Hab. Ceylon.[1]

24. P. OBSOLITA, Saussure, *l. c.* 56, f. 37.[1]
Hab. Ceylon.[1]

25. P. PLEBEJA, Sauss.
Saussure, *Hym. d. Novara Reise*, 57.[1]
Hab. Ceylon.

26. P. VEDA, Cam. postia.
Hab. Poona (*Wroughton*).

PSEUDAGENIA CAERULEUS, *Smith.*

A specimen from Barrackpore is probably this species; but the description is rather incomplete. The clypeus at the apex is broadly rounded, the sides obliquely truncated; the ocelli in a triangle and separated from the eyes by a somewhat greater distance than they are from each other; occiput slightly concave; sides of pronotum rounded; shorter than the head; second and third cubital cellules subequal; the first recurrent nervure received shortly before the middle of the cellule; the second about half the length of the transverse cubital nervure from the base. I cannot see the "fuscous cloud transversing the externo-medial nervure," nor "a faint cloud" in the second submarginal cellule. The apex of the hind femora is black, a fact not mentioned by Smith for his *cærulea*. It is possible that my specimen may be *cyaneus*, Lep., but that has the third cubital cellule "plus grande que la deuxième." The median segment at the apex rounded, transversely striated, and having a gradually-rounded slope to the apex; the apex also having a tuft of white hair on either side; the upper part of metapleuræ obliquely striated; the long spur of the hind tibiæ does not reach the middle of the metatarsus; the

base of the latter with a thick hair brush; the other joints with short spines beneath; the fore tarsi pilose beneath.

PSEUDAGENIA FESTINATA, *Smith.* (Pl. III. f. 3).

This species, I consider, identical with *P. alaris*, Sauss. Smith's type is smaller, and the wings have not the yellowish tint quite so marked.

PSEUDAGENIA CELÆNO, *Smith.*

A ♂ from Barrackpore, is, perhaps, this species—at least it agrees fairly well with the description so far as that goes. The eyes distinctly converge towards the apex; the clypeus is transverse at the apex; the sides being oblique; the ocelli form a triangle, and are separated from each other by a perceptibly less distance than they are from the eyes; the second and third cubital cellules at the top and bottom are subequal; the first recurrent nervure is received a little before the middle; the second in the basal third of the cellule; the nervures are pale testaceous. From *alaris* it is easily known by the truncated apex of the clypeus. The long spur of hind tibiæ does not reach the apex; the metatarsal brush slight.

PSEUDAGENIA ARIEL, *sp. nov.*

Black, shining, pubescent, eyes distinctly converging beneath, the space separating them at the top being distinctly greater than at the bottom. Ocelli in a triangle; the hinder separated from each other by a less distance than they are from the eyes. Clypeus convex, the basal half laterally oblique; the apical curved, terminating in a blunt point. Occiput bluntly rounded. An indistinct furrow runs from the ocelli to the antennæ. The head is convex in front, shining, finely punctured, sparsely covered with long silvery hairs; the cheeks and clypeus bear a silvery pubescence; antennæ longish, stout, pruinose, tapering

towards the apex. Mandibles at the base finely rugose. Pronotum broad, broadly rounded in front, behind concave. Median segment short, with a rather abrupt slope, transversely striated. The thorax above in front is shining, minutely punctured, laterally opaque, alutaceous, the median segment transversely striated. Abdomen shining, pruinose; the apical segment above shining, impunctate, sparsely covered laterally with long pale hairs. Wings sub-hyaline; the second cubital cellule above slightly longer than the third; below a little shorter; the first recurrent nervure is received a little before the middle; the second in the basal third. Legs pruinose; the long spur of the hind tibiae does not reach the middle; tarsi with a few fulvous spines.

PSEUDAGENIA VEDA, *sp. nov.*

Black, wings clear hyaline; a small fuscous cloud below and touching the stigma. Eyes a little converging, the hinder ocelli separated from each other by a very slightly less distance than they are from the eyes. Clypeus short, convex, the apex broadly rounded. Occiput slightly concave in the middle. The front strongly aciculate; the vertex shining, almost impunctate. The head, except on the vertex densely covered with a silvery pubescence; the vertex with a few fuscous hairs; the lower and outer orbits with some long silvery ones. Pronotum shorter than the head, roundly narrowed towards the head, shallowly concave behind. Pro- and meso- thorax alutaceous; the median segment with a rounded slope, irregularly transversely striated; deeply furrowed down the centre, the sides covered with long whitish hairs. Abdomen shining; pruinose, having an olive tint, the petiole with a distinct neck. Radial cellule wide, angled where the cubital nervures are received; the second cubital cellule at the top distinctly shorter than the third, especially on the lower side; the first and second transverse cubital nervures with

a slight oblique curve; the first recurrent nervure is received a little beyond the middle; the second at a less distance from the base. Legs densely covered with a silvery pile; the long spur of the hind tibiæ not much more than a third of the length of the metatarsus; the front spurs pale, the front tarsi fuscous; the tibiæ with short spines; the metatarsal brush slight.

This species differs from the others in having the basal nervure interstitial; but in other respects it agrees with the generic character.

Length 7mm.

PSEUDAGENIA TINCTA, *Smith.*

Black, densely pruinose, the hinder femora red, wings hyaline, the nervures black. Eyes curved, converging beneath and at top. Ocelli separated from the eyes by a somewhat greater distance than they are from each other. Clypeus broadly convex, broadly rounded at the apex. Occiput slightly convex, the sides rounded. A shallow furrow runs down from the ocelli. Head opaque, alutaceous; the clypeus and cheeks densely covered with a silvery pubescence; the front and vertex sparsely silvery pubescent, shewing fuscous hairs. Antennæ stout, involute. Thorax alutaceous, covered with a silvery pubescence; the pleurae and median segment with long soft white hairs; the pronotum short, bulging out roundly laterally, behind slightly curved, angled in the middle. Median segment obscurely transversely striolate, indistinctly channelled down the centre. Petiole with a distinct neck, becoming gradually widened towards the apex; the abdomen shining, laterally, and at the apex densely pruinose; the apical segment impunctate, the apex with fulvous hairs. Radial cellule elbowed slightly where the first and third transverse cubital nervures are received; the second cubital cellule a little shorter than the third at top and bottom;

the first recurrent nervure is received a little in front of the middle of the cellule; the second in the basal third. Legs elongated, pruinose; the long spur of the hind tibiæ does not reach the middle of the cellule. The abdominal segments are testaceous at the apex.

It is probable that this is *P. tinctus*, Smith, with which it agrees in colouration (the only point noted in the description), except that I fail to notice any trace of "green tinge" about the head and thorax. The four anterior femora may be entirely black, or more or less reddish.

It is probably *varipes*, Dbm.

SALIUS, *Fab.*, sec. *Kohl.*

Salius, Fab., *Syst. Piez.*, 124; Kohl, *Verh. z-b, Ges. Wien*, 1884, 43.

Procnemis, Schiödte, *Mon. Pomp. Kröyer Tidsskr.*, I, 1837.

Hemipepsis, Dbm., *Hym. Eur.*, I., 462.

Homonotus, Dbm., *l. c.* 441, *pt.*

Entypus, Dbm., *l.c.*, 442.

Pallosoma, Smith, *Cat. Hym.*, III., 181.

The following species are in all probability referrable to *Hemipepsis*.

1. SALIUS ÆRUGINOSA, Sm.

Mygnimia æruginosa, Smith, *Cat. Hym.* III., 184, 8[1].

Hab. Sumatra[1].

2. S. ALBIPLAGIATA.

Mygnimia albiplagiata, Smith, *l.c.* 183, 6[1].

Hab. Java[1].

S. AUDAX, Smith.

Mygnimia audax, *l.c.* 182, 4[1]; Bingham, *Journ. Bourb. Nat. Hist. Soc.* V. 239[2].

Hab. Silhet[1]; Kumaon[2].

3. S. ANTHRACINA, Sm.

Mygnimia anthracina, Smith, *lc.*, 183, 5.[1]

Hab. Malacca, Borneo, Singapore, Sumatra.[1]

4. S. AUREOSERICEA, Guér.
Pompilus aureosericus, Guér., *Voy. Coq.*, II., 256.[1]
Mygnimia aureosericea, Smith, *Cat. Hym.*, III., 182, 3.[1]
Hab. Java.[1]

5. S. AVICULUS, Sauss.
Mygnimia avicula, Saussure, *Novara Reise*, 64, fig. 28.[1]
Hab. Java.[1]

6. SALIUS BELICOSUS, Sm.
Mygnimia belicosa, Smith. *Ann. Mag. Nat. Hist.*, 1873, 256.[1]
Hab. Bengal.[1]

7. SALIUS CEYLONICUS, Sauss.
Mygnimia ceylonica, Saussure, *Novara Reise*, 64.[1]
Hab. Ceylon.[1]

8. S. CYANEUS, Lep.
Pallosoma cyanea, Lep., *Nat. Hist. Hym. Ins.* III., 493.[1]
Hab. Java.[1]

9. S. DUCALIS, Sm.
Mygnimia ducalis, Smith, *Proc. Linn. Soc.*, II., 983.[1]
Hab. Malacca, Sumatra.[1]

10. S. EXCELSUS, Cam.
Mygnimia atropos, Smith, *Trans. Ent. Soc*, 1875, 36, *non.*, Smith, 1855.
Hab. Barrackpore[1] (*Rothney*).

11. S. FLAVUS, Fab.
Pompilus flavus, Fab., *Syst. Piez.*, 197, 2; Lep. *Nat. Hist. Hym. Ins.*, III., 430, 2.[1]
Sphex flava, Drury, *Ill. Exot. Ins.*, III. t., 42, f. 4, ♀.
Hemipepsis flavus, Dbm., *Hym. Ent.*, I., 123.
Hab. Borneo, Singapore, Gilolo, Sumatra (*teste* Smith).

12. S. FLAVICORNIS, Fab.
Pepsis flavicornis, Fab *Syst. Piez.* 216, 44[1].
Hab. Malabar.[1]

13. S. FUNESTUS, Cam.
Mygnimia fenestrata, Smith, *Cat. Hym. Ins.*, III. 184, 10[1] (*nec* Smith, *l.c.* p. 147).
Hab. Silhet[1]

14. S. GROSSUS, Fab.
Pepsis grossa, Fab., *Syst. Piez.* 214, 32[1]; Lep. *Nat. Hist. Hym. Ins.*, III. 487; Dbm. *Hym. Eur.* I. 464.
Hab. India.[1]

15. S. HERCULES, Cam. *postea*.
Hab. Naga Hills.

16. S. FULVIPENNIS, Fab. (Pl. III. f. 28).
Sphex fulvipennis, Fab., *Ent. Syst.* II., 218, 84.
Pompilus fulvipennis, Fab., *Syst Piez*, 189, 57.
Hemipepsis fulvipennis, Dbm., *Hym. Eur.* I., 462, 2.
Pompilus fulvipennis, Saussure, Novara Reise, 58[1].
Hab. Madras (*Rothney*), Ceylon[1].

17. S. INDICUS, Cam. postea.
Hab. Tavoy.

18. S. INTERMEDIUS, Smith.
Mygnimia intermedia, Smith, *Ann. Mag. Nat. Hist.*, 1873, 257[1].
Hab. North India[1], Ceylon.[1]

19. S. IRIDIPENNIS, Smith.
Mygnimia iridipennis, Smith, *Proc. Linn. Soc.* II. 98, 5[1].
Hab. Malacca[1], Borneo[1], Ceram[1], Timor[1].

20. S. LUSCUS, Fab.
Pepsis lusca, Fab., *Syst. Piez.* 215, 38[1].
Priocnemis luscus, Dbm., *Hym. Eur.*, I., 45. 7[2].
Hab. Tranquebar[1], Port Natal[2] (?).

21. S. LÆTA, Sm.
Mygnimia læta, Smith, *Ann. Mag. Nat. Hist.*, 1873, 256[1]
Hab. Burma.[1]

22. S. MEGÆRA, Cam.
Mygnimia perplexa, Sm.. *Cat. Hym.*, III., 185, 11[1] (*non l.c.*, p. 147).
Hab. Madras.[1]

23. S. MOMENTOSUS, Sm.
Mygnimia momentosa, Sm., *l.c.*, 258.[1]
Hab. Borneo.[1]

24. S. NIGRITUS, Lep.
Pallasoma nigrita, Lep., *Nat. Hist. Hym. Ins.*, III., 493.[1]
Hab. Java.[1]

25. S. PRINCEPS, Sm.
Mygnimia princeps, Smith, *Proc. Linn. Soc.* II. 98, 4.[1]
Hab. Borneo.

26. S. PURPUREIPENNIS, Smith.
Mygnimia purpureipennis, Smith, *Ann. Mag. Nat. Hist.*, 1873, 258.
Hab. Java.[1]

27. S. RUBIDA, Bing.
Mygnimia rubida, Bingham, *Jour. Bomb. Nat. Hist. Soc.* V. 238.[1]
Hab. Ceylon.

28. S. SÆVISSIMA, Sm.
Mygnimia sævissima, Smith, *Ann. Mag. Nat. Hist.*, 1873, 256.[1]
Hab. Bombay Presidency.[1]

29. S. SEVERUS, Drury.
Sphex severus, Drury, *Ill. Exot. Ins.*, III., t. 42, f. 4.[1]
Mygnimia severa, Smith, *Cat. Hym. Ins.*, III., 182, 1.
Hab. India.[1]

30. S. VEDA, Cam., *postea*.
Hab. Poona (*Wroughton*).

31. S. VITRIPENNIS, Sm.

Mygnimia vitripennis, Smith, *Ann. Mag. Nat. Hist.*, 1873, 257.[1]

Hab. Sumatra.[1]

To this section is probably referrable:—

PEPSIS DISELENE, Smith, *Cat. Hym.*, III., 200, 51.

Hab. India, Singapore.

SALIUS (MYGNIMIA) EXCELSUS, *Cam.*

Has the typical *Hemipepsis* wing. Head slightly convex in front and behind. Eyes not arcuate at top, parallel or nearly so; ocelli in a curve; the posterior separated from each other by a distinctly greater distance than they are from the eyes; the ocellar region raised, a depression on either side of it. Clypeus convex, the apex depressed, waved inwardly in the centre. Pronotum a little shorter than the head, the sides rounded, narrowed towards the base; the apex roundly concave. Pronotum short, sharply oblique from base to apex, there being no break in the surface from the base to the apex; the lateral tubercles distinct. Abdomen subsessile; the apex with a thick tuft of hair. The third cubital cellule at the top is a little longer, at bottom considerably shorter than the second; the second recurrent nervure received a little before the middle—a little less than the length of the second transverse cubital nervure; the anal nervure in hind wings interstitial. The long spur of the hind tibiæ reaches beyond the middle of the metatarsus.

There is another larger species (22 mm.) which resembles *excelsus* in colouration, except that the body has a bluish tinge, and the wings have a deep purple iridescence. This is probably *vitripennis*, Sm., from Sumatra. From *excelsus* it is easily known by the median segment having an oblique slope to the apex, when it curves down obliquely; the anal nervure in hind wing is received beyond the cubital—the ocelli are larger.

SALIUS (HEMIPEPSIS) ANTHRACINA, *Sm.*

This species has the head in front concave, but with the antennal tubercles large, projecting; the eyes parallel from the top; the ocelli large, separated from the eyes by one and a half times the distance the posterior are from each other; the pronotum rounded in front; concave behind: base of abdomen subsessile; apical segment covered with stiff blackish pubescence, roughened. Tibiæ and tarsi thickly spurred; the long spur of the hind tibiæ not one-fourth the length of the metatarsus; thick, obliquely narrowed towards the apex; claws with two stout spines. In the hind wings the anal-nervure is received a little beyond the cubital. Clypeus transverse at apex, projecting.

SALIUS HERCULES, *sp. nov.*

Black; the face, orbits, tibiæ and tarsi dull brown, the flagellum dull ferruginous, blackish above at the base; wings at the base (to a little beyond the basal nervure), deep blackish-violaceous, the rest brownish-yellow, except at the apex which is infuscated. Head almost transverse in front, behind slightly convex, piceous. Eyes parallel, very little arcuate above; ocelli large, in a curve, the hinder separated from the eyes by a perceptibly less distance than they are from each other. Clypeus moderately convex, below the eyes projecting nearly as much as half the length of the mandibles; broader than long; transverse at the apex; labrum rounded at the apex, nearly half the length of the clypeus. The ocellar region slightly raised, a furrow at the sides of the region, the inner orbits narrowly edged with obscure testaceous; the head thickly covered with a black to fuscous pubescence. Thorax opaque, thickly covered with a blackish pubescence; the prosternum and anterior coxæ with long blackish hairs. Pronotum as long as the head, rounded and narrowed in front, behind convex. Scutellum gibbous, becoming gradually raised

and narrowed to the apex which is rounded; metanotum forming a longer tubercle, oblique, haired at the sides, the top rounded, glabrous, and brown. Median segment with a slight straight slope to the apex, which is oblique; transversely striolate; the basal tubercles not very distinct. Metapleuræ shining, impunctate, almost glabrous. Abdomen subsessile, smooth, shining, obscurely pruinose; the apical segments with long hairs. Legs long, stout, the hinder longer than the body, their tibiæ with a row of sharp moderately long spines; the tarsi also spined; the metatarsus with the brush distinct; the long spur of the hind tibiae reaching somewhat beyond the middle of the metatarsus; the tarsal joints blackish at the apex; the claws bidentate. Antennæ stout, bare; the third joint a little longer than the fourth. The second recurrent nervure is received the length of the second transverse cubital cellule from the base of the cellule; the first interstitial; the anal nervure in hind wings interstitial. ♂.

Length 33 mm.

Nearly related to *S. anthracina*, Sm., which differs from it in the ocelli being smaller, and separated from the eyes by a greater distance than they are from each other; in the clypeus being rounded, and in the form of the scutellum, metanotum and median segment.

Hab. Naga Hills.

SALIUS (MYGNIMIA) INDICUS, *sp. nov.*

Black: the antennæ, abdomen and legs ferruginous; the basal half of petiole and coxæ and trochanters, black; the mandibles ferruginous, piceous at the apex; wings deep violaceous. Head transverse before and behind, the eyes projecting beyond the face in front; eyes parallel; at top very slightly arcuate; the ocelli large, in a triangle, the posterior separated from the eyes by a greater distance than they are from each other; a distinct furrow runs down from

them. Clypeus with the sides oblique, the apex shining, smooth, slightly arcuate; apex of labrum with a slight inward curve. Antennæ short, thick, involute; the third joint nearly twice the length of the fourth. Prothorax shorter than the head, narrowed and rounded towards the base, in front broadly convex. Median segment with a gradually rounded slope to the apex which is almost transverse, transversely striolated; the sides at the base broadly depressed laterally and with a broad raised margin; the lateral tubercles elongate. Abdomen subpetiolate, a little longer than the head and thorax united; acute at the apex, the apical segment with scattered punctures and (especially at the apical half) bearing long black hairs; beneath it is punctured, except at the base. Legs of moderate length, stout, the tibiæ and tarsi with golden pubescence, the hind tibiæ sparsely spinose; the long spur of the hind tibiæ does not reach the middle of the metatarsus, metatarsal brush incomplete; the other joints spined. The second recurrent nervure is curved, and is received about the length of the second transverse cubital nervure from the base of the cellule; at the top the second cubital cellule is much shorter than the third; at the bottom they are subequal. In the hind wings the anal nervure is received beyond the apex of the cubital.

Length 23 mm.

Hab. Tavoz, *Mus. Cal.*

A well marked species.

SALIUS (MYGNIMIA) VEDA, *sp. nov.*

Black; the abdomen and legs rufous; the scape beneath and orbits and the face obscure yellowish; the flagellum brownish beneath; wings dark smoky-fuscous. Eyes a little converging beneath; ocelli separated from each other by a greater distance than they are from the eyes, situated on a raised space; a narrow furrow surrounding them, and with a

depression in front of the anterior. Clypeus broadly convex; the apex rounded; the labrum projecting beyond it; a deepish depression on the sides of the clypeus at the base; occiput transverse in the middle, the sides rounded. Pronotum shorter than the head, a little narrowed anteriorly. Median segment with a slight slope to the apex, when it becomes oblique; apex bluntly rounded. Head and thorax alutaceous, bearing a pale thick whitish pile, the median segment having also some fuscous hairs. Antennæ stout, shorter than the body, the joints dilated beneath; the third and fourth subequal. Abdomen shining, slightly pruinose; the basal 2-joints black. Wings large; the basal abscissa of radius short, a little oblique; the second straight, the third sharply oblique; the first transverse cubital nervure very oblique, the second nearly straight, the third curved, roundly elbowed at the top: the second cubital cellule at the top distinctly shorter than the third, at the bottom fully longer than it: the first recurrent nervure almost interstitial; the second received a little before the middle; the first discoidal nervure bullated; the basal nervure elbowed at the middle. Legs elongate, stout; the tibiæ with a few spines; the coxæ and trochanters black, the greater part of the hind tarsi fuscous; the long spur of the hind tibiæ does not reach the middle of the metatarsus; claws with a tooth in the centre, tibiæ sparsely spined.

Length slightly over 9 mm.

Hab. Poona (*Wroughton*).

The following are all referrible, no doubt, to *Priconemis*, Kohl's section 2.

30. S. CANIFRONS, Sm.

Pompilus canifrons, Smith, *Cat. Hym.*, III., 146, 138.[1]

Hab. Sumatra[1], Poona (*Wroughton*).

31. S. CONCOLOR, Saus.

Priconemis concolor, Saussure, *Novara Reise*, 54.[1]

Hab. Ceylon.[1]

33. S. CONVEXUS, Bingham.
Priconemis convexus, Bingham, *Jour. Bomb. Nat. Hist. Soc.*, v., 237.
Hab. Ceylon.[1]

32. S. CONSANGUINEUS, Sauss.
Priconemis consanguineus, Saussure, *Hym. Novara Reise*, 62.[1]
Hab. Ceylon.[1]

34. S. COTESI, Cam., *postea.*
Hab. S. India.

35. S. CRINITUS, Bing.
Priconemis crinitus, Bingham, *Jour. Bomb. Soc. Nat. Hist.*, v., 238.[1]
Hab. Ceylon.[1]

36. S. FULGIDIPENNIS, Sauss.
Priconemis fulgidipennis Saussure, *Hym. Novara. Reise*, 61.
Hab. Ceylon.[1]

37. S. GIGAS, Tasch.
Priconemis gigas, Taschenberg, *Zeits. Gess, Naturwiss.* XXXIV., 40.[1]
Hab. Java.

38. S. HUMBERTIANUS, Saus.
Priconemis humbertianus, Saussure, *Hym. Novara Reise.*
Hab. Ceylon.[1]

39. S. JUNO, Cam., *Infra.*
Hab. Barrackpore.

40. S. MADRASPATANUS, Smith.
Pompilus Madraspatanus, Smith, *Cat. Hym.*, III. 144, 130.[1]
Hab. Madras,[1] Nicobar Islands.

41. S. MELLERBORGI, Dbm.
Priconemis Mellerborgi, Dbm., *Hym. Eur.* I., 458.
Hab. Java.[1]

42. S. MIRANDA, Cam. *postea.*
Hab. Barrackpore.

43. S. PEDESTRIS, Sm.
Pompilus pedestris, Smith, *Cat. Hym.*, III., 147, 139.
Hab. Sumatra.[1]

44. S. PERPLEXUS, Sm.
Pompilus perplexus, Smith, *Cat. Hym. Ins.* III., 147, 140.
Hab. Sumatra.[1]

45. S. PEDUNCULATUS, Sm.
Pompilus pedunculatus, Smith, *Cat. Hym. Ins.*, III., 145, 131.[1]
India.[1]

46. S. PEREGRINUS, Sm. (Pl. III. f. 19.)
Priconemis peregrinus, Smith, *Trans. Ent. Soc.*, 1875.
Hab. Barrackpore (*Rothney*).

47. S. ROTHNEYI, Cam., *Infra.*
Hab. Barrackpore.

48. S. SERICOSOMA, Sm.
Pompilus sericosoma, Smith, *Cat. Hym.*, III., 146, 137.[1]
Hab. Sumatra.[1]

49. S. OPTIMUS, Sm.
Priconemis optimis, Smith, *Jour. Linn. Soc.*, II., 93, 5.[1]
Hab. Singapore.[1]

50. S. VERTICALIS, Sm.
Priconemis verticalis, Smith, *Proc. Linn. Soc.*, II., 94, 6.
Hab. Borneo, Malacca.[1]

51. S. WAHLBERGI, Dbm.
Priconemis Wahlbergi, Dbm, *Hym, Eur.*, I., 458.[1]
Hab. Java.[1]

SALIUS ROTHNEYI, *sp. nov.*

Black, pruinose; eyes a little diverging beneath, straight. Ocelli in a triangle, separated from the eyes by a somewhat greater distance than they are from each other. Clypeus a little projecting towards the apex, which is broadly rounded and margined. Occiput transverse, rounded at the sides. There are two broad ridges above the antennæ, having a smooth, shining fovea between them. Head opaque, finely and closely punctured; the clypeus has the punctures distinctly separated, and it is more shining. The cheeks and clypeus bear a close silvery pubescence and some long silvery hairs; the vertex bears long fuscous hairs. Mandibles finely punctured at the base; the apex piceous. Pronotum short, in front obliquely transverse laterally; behind arcuate. Median segment shorter than the mesothorax, broadly and gradually rounded; thorax opaque, finely and closely punctured; median segment towards the apex transversely striolate; the central furrow indistinct. Abdomen shining, indistinctly pruinose; the apical segments finely punctured and covered with longish fuscous hairs; the terminal segment acute at apex; the petiole at the base about one third of the width of the apex. Antennæ shortish, pruinose. Wings hyaline, with a slight fuscous tinge; a cloud at the basal nervure; a broader one extending from the apex of the stigma to near the apex of the radial cellule. Second cubital cellule obliquely quadrate; at the top one-half longer than the third at the top; at the bottom a little shorter. The first recurrent nervure is received in about the apical third of the cellule; the second distinctly before the middle. Legs pruinose; the long spur of the hind tibiæ reaching to the middle of the metatarsus; the tibial spines stout, the central very thick, somewhat triangular at the apex, the metatarsal brush long,

thick, the tarsal joints spined and pilose beneath; the front tarsi without a brush.

Length, 10 mm.

SALIUS COTESI, *sp. nov.* (Pl. III. f. 3).

Similar in the colouration of the body to *S. rothneyi*, as also in having in the wings three clouds, but abundantly distinct in structure. The clypeus at the apex is shining, and transverse in the middle; the elongated ridges above the antennæ, so prominent in *Rothneyi*, are absent, as is also the shining fovea, but there is a small carina there; the eyes distinctly diverge beneath; the ocelli are in a triangle, and closer to each other; the hinder being separated from the eyes by twice the distance they are from each other; the median segment at the apex is more abrupt; the abdomen is longer, being as long as the head and thorax united, and its apical segments are not so thickly haired; the form of the second cubital cellule is very different; the first transverse cubital nervure is elbowed at the middle, and bends towards the second, making the top of the cellule there about one-fourth of what it is at the bottom, and about one-third of the length of the top of the third; at the bottom, the second cubital cellule is about three-fourths of the length of the third; the second transverse cubital nervure is sharply elbowed at the top, making the cellule much narrower at the top than at the bottom, where it is rounded broadly at the apex, instead of acutely angled as in *Rothneyi*, while the cubital nervure terminates completely there; the first recurrent nervure is received a very little beyond the middle; the second at a less distance from the transverse cubital nervure than is the first; the radial nervure becomes elbowed about the basal third (and also more sharply), while in *Rothneyi* it turns up at the middle of the cellule. *S. cotesi* also is larger, being 13 mm. in length. The long spur of the hind tibiæ does not reach the middle of metatarsus; the tibial spines are shorter and fewer.

SALIUS (PRICONEMIS) PEREGRINUS, *Sm.* (Pl. III. f. 4).

Eyes curved above, slightly converging beneath. Ocelli almost in a triangle, the posterior separated from the eyes by a somewhat greater distance than they are from each other. Clypeus convex, transverse at the apex, the sides rounded. Prothorax shorter than the head; the sides obliquely dilated towards the head, convex above, the centre furrowed, the dilated part narrowing towards the base of the furrow; behind concave. Median segment at apex transverse, the apical part obliquely sloped, depressed in middle, and striolate. Radial cellule lanceolate at apex, elongate, narrow; third cubital cellule at top shorter, at bottom longer than the second. The second recurrent nervure is received shortly before the middle. In the hind wings the anal nervure is interstitial. The long spur of the tibiæ hardly reaches to the middle of the metatarsus. In the ♂ the antennæ are nearly as long as the body, stout, tapering towards the apex; the third and fourth joints subequal. In the ♂ the apical abdominal segment bears a thick longish tuft of black hairs.

SALIUS PEDUNCULATUS, *Sm.*

I have a number of specimens which are probably referrible to this species. Head alutaceous, the eyes curved, a little converging beneath; ocelli in pits, small, the hinder separated from the eyes by a greater distance than they are from each other. Head almost transverse in front, a little convex behind. Clypeus piceous and transverse in the middle at the apex; the sides rounded; mandibles yellow at the base. Pronotum slightly shorter than the head; slightly narrowed towards the head; rounded at the base; the apex a little curved inwardly. Median segment gradually rounded to the apex, as long as the mesothorax,

transversely striated. Abdomen subpetiolate, the petiole becoming gradually dilated to the width of the second segment; the apical segments smooth, glabrous, except at extreme apex. The long spur of the hind tibiæ does not reach to the middle of the metatarsus, tibiæ sparsely spined. The second cubital cellule at top and bottom distinctly longer than the third; the first recurrent nervure is received a little beyond the middle; the second a little beyond the basal third. In the hind wings the anal nervure is received before the termination of the cubital. In length my specimens average 12 mm.

SALUIS JUNO.

Black; the abdomen reddish, black at the base; the knees and fore tarsi rufo-testaceous; wings subhyaline, the apex smoky. Eyes curved, converging a little at the bottom. Ocelli separated from the eyes by nearly the same distance that they are from each other. Clypeus broadly convex; the sides at the apex oblique, the middle rounded. Occiput slightly concave. Prothorax nearly as long as the head, not much, if at all, narrowed towards the base. Median segment as long as the mesothorax, gradually rounded to the apex, irregularly transversely striated. Head and thorax alutaceous, covered with a pale pile. Abdomen pruinose; the petiole with a distinct neck at the base. Antennæ moderately elongate, microscopically pilose. The second cubital cellule at top and bottom considerably longer than the third; the first and third transverse cubital nervures obliquely curved; the second straight, slightly oblique; both the recurrent nervures received a little beyond the middle. The wings are rather short. Legs elongate, moderately stout, pruinose, the coxæ white with a silvery pile, the tibial spurs sparse, golden-fulvous; the apex of the hind tibiæ and the base of the tarsus bearing a thick fulvous

pile; the long spur of the hind tibiæ does not quite reach to the middle of the metatarsus.

Length, 8 mm.

Hab. Barrackpore (*Rothney*).

POMPILUS.

Pompilus, Fab., *Ent. Syst. Supp.* 246.
Ferreola, Smith, *Cat. Hym.* III., 167.

1. POMPILUS ANALIS, Fab.
   Pompilus analis, Fabricius, *Syst. Piez.*, 188, 4; Dbm., *Hym. Eur.*, I., 47; Lep., *Nat. Hist. d. Ins. Hym.*, III., 439, 35.
   Hab. Common and widely distributed over our region, Singapore, Java, Bachian, Celebes, Aru.
2. POMPILUS ARIADNE, Cam., *postea.*
   Hab. Barrackpore.
3. P. BEATUS, Cam., *postea.*
   Hab. Bungalore.
4. POMPILUS BRACATUS, Bingh., *Jour. Bomb. Nat. Hist. Soc.*, V., 236.
   Hab. Pegu Hills.
5. POMPILUS BUDDHA, Cam, *infra.*
   Hab. Poona (*Wroughton.*)
6. P. CIRCE, Cam. Pl. III. f. 5.
   Ferreola fenestrata, Smith, *Cat. Hym. Ins.* III., 169[1]. *non* Smith, *l.c.* p. 144.
   Hab. Madras[1], Poona (*Wroughton*).
7. P. COMPTUS, Lep.
   Nat. Hist. Ins. Hym. III., 425, 3[1].
   Hab. India[1].
8. P. COTESI, Cam. *infra.*
   Hab.

9. P. CORIARIUS, Tasch.
Zeit. f. gess. Natur. Wessen. XXXIV., 49, 1.
Hab. Java, Singapore[1].

10. P. DEHLIENSIS, Cam., *infra.*
Hab. Dehli (*Rothney*).

11. P. DETECTUS, Cam.
Hab. Barrackpore (*Rothney*).

12. P. DORSALIS, Lep.
Nat. Hist. d. Ins. Hym., III., 407, 13.[1]
Hab. India.[1]

13. P. DIMIDIATIPENNIS, Sauss.
Ferreola dimidiatipennis, Saussure, *Hym. Novara Reise*, 47.[1]
Hab. Ceylon.[1]

14. P. ELECTUS, Cam. *postea.*
Hab. Barrackpore (*Rothney*).

15. P. FENESTRATUS, Sm.
Cat. Hym. Ins., III., 144, 128.[1]
Hab. Bengal.[1]

16. P. FASCIATUS, Bingh.
Ferreola fasciata Journ., Bomb., Nat. Hist. Soc. V., 241, 12.
Hab. Burmah.

17. P. GRAPHICUS, Sm.
Cat. Hym. Ins., III., 148, 143.[1]
Hab. Phillipines.[1]

18. P. GREENII, Bingh.
Ferreola Greenii, Bingham, *Jour. Bomb. Nat. Hist. Soc.*, V., 240, 11.[1]
Hab. Ceylon.[1]

19. P. HECATE, Cam., *postea.*
Hab. Barrackpore (*Rothney*).

20. P. HONESTUS, Sm.,
Smith, *Cat. Hym. Ins.* III., 144, 129.[1]
Hab. India.

21. P. HERO, Cam. *postea.*
Hab. Barrackpore.

22. P. IGNOBILIS, Saussure.
Hymen. d. Novara Reise, 60.[1]
Hab. Ceylon.[1] Sikim.

23. P. INCOGNITUS, Cam. *postea.*
Hab. Barrackpore (*Rothney*).

24. P. LASCIVUS, Cam. *postea.*
Hab. Barrackpore (*Rothney*).

25. P. LEUCOPHÆUS, Sm.
Proc. Linn. Soc. II., 921.[1]
Hab. Malacca.[1]

26. P. LUCIDULUS, Sauss.
Homonotus lucidulus, Saussure, *Hym. d. Novara Reise*, 50.
Hab. Ceylon.[1]

27. P. MACULIPES, Sm. (Pl. III, f. 16).
Trans. Linn. Soc. VII., 186 1.[1]
Hab. Manipuri, North West Provinces.

28. P. MIRANDA, Sauss.
Ferreola miranda, Saussure, *Hym. d. Novara Reise*, 49.[1]
Hab. Ceylon, Trincomalia.[1]

29. P. PARTHENOPE, Cam., *infra.*
Hab. South East Provinces.

30. P. PEDALIS, Cam., *infra.*
Hab. Barrackpore (*Rothney*).

31. P. PULVEROSUS, Smith.
Proc. Linn. Soc. II., 93, 3[1].
Hab. Borneo.[1]

32. P. ROTHNEYI, Cam. *postea.*
Hab. Barrackpore (*Rothney*).

33. P. RUFO-UNGUICULATUS, Tasch.
Zeits f. ges. Natur. Wissen XXXIV., 5, 4, 9.
Hab. Java.

34. P. UNIFASCIATUS, Smith.
Proc. Linn. Soc. III., 145. 133.[1]
Hab. India,[1] Sumatra.[1]

35. P. VAGABUNDUS, Sm. (Pl. III. f. 23).
Proc. Linn. Soc. II., 92, 2.[1]
Hab. Borneo,[1] Barrackpore, Mussoure, (*Rothney*).

36. P. TRICOLOR, Sauss.
Ferreola tricolor, Saussure, *Hymen. d. Novara Reise*, 48.[1]
Hab. Singapore.[1]

37. P. VISCHNU, Cam., *postea.*
Hab. Barrackpore.

38. P. VIVAX, Cam., *postea.*
Hab. Barrackpore.

39. P. WROUGHTONI, Cam., *postea.*
Hab. Poona (*Wroughton*).

40. P. ZEBRA, Cam., *postea.*
Hab. Shellong.

41. P. ZEUS, Cam., *postea.*
Hab. Barrackpore (*Rothney*).

Section—FERROLA.

FERROLA FENESTRATA, *Bingham.*

This is a distinct species from *fenestrata*, Smith, which has only the prothorax reddish. It is probably undescribed.
Hab. Burmah.

POMPILUS CIRCE, *Cam.* (Pl. III f. 5).

This is the most conspicuous species of the section. The collar is more elongated, is transverse at the apex in the middle, but curves round to the tegulæ at the sides; the clypeus is rounded; the ocelli small, in a curve, and separated from each other by a much greater distance than they are from the eyes.

POMPILUS PEDALIS, *sp. nov.*

Black, the basal two segments entirely, and the basal two-thirds of the third, red; the head and thorax densely covered with grey pile; the wings fusco-violaceous, the base to the transverse basal nervure subhyaline. Eyes arcuate, distinctly converging beneath. Ocelli large, in a curve, separated from each other by a much greater distance than they are from the eyes; the anterior in a pit; and an oblique short furrow runs from the posterior. Clypeus short, subarcuate. The head almost hoary with a greyish-white pubescence; on the top it is shorter, convex in front, concave behind. Occiput convex. Prothorax longer than the head, longer than broad, narrowed towards the head; at apex angled in the centre. Median segment as long as the prothorax; with a very slight slope above, the sides at the apex projecting into a longish sharp triangular tooth. Abdomen sessile, longer than the head and thorax united; pruinose, the apical segment impunctate. Antennæ short, about as long as the thorax, stout. Legs densely pruinose; the hinder tibiæ sparsely spined; the hind tibiæ not much longer than the metatarsus; the long spur of the hind tibiæ reaches to the middle of the latter. For wings see fig 6, pl. III. Claws bifid at apex; the tarsi without a brush.

This species differs from the other species here noticed, in the eyes being more arcuate at the top and converging much more at the bottom.

POMPILUS (FERREOLA) ARIADNE, *sp. nov.* (Pl. III. f. 7, 7*a*).

Black, the spurs white, palpi yellow, mandibles reddish, wings subhyaline. Head smooth and shining, sparsely pubescent; eyes arcuate, equally converging at top and bottom; ocelli large, in a curve; the posterior separated from each other by more than twice the distance they are from the eyes. Head convex in front, concave behind; antennæ placed immediately over the clypeus, over which the front projects; clypeus rounded at the apex. Prothorax quadrate, longer than the head, not narrowed towards the head; behind almost transverse. Pleuræ compressed, impunctate, almost glabrous. Median part of scutellum broad, a little narrowed towards the apex; median segment longer than the mesothorax; depressed in the middle at the apex; the lateral projections acutely triangular; the apex bearing depressed longish hairs. Abdomen sessile, compressed laterally; the third and following segments covered with dense silvery hairs. Legs stout; the tarsi testaceous; the long and stout calcaria longer than the metatarsus; claws bifid. For wings see fig. 7, pl. III.

Length, 6 mm.

Hab. Barrackpore (*Rothney*).

A very distinct little species.

POMPILUS (FERREOLA) HECATE, *sp. nov.* (Pl. III. f. 8).

Black, pruinose, the face densely covered with a silvery pile, the wings hyaline, the apex infuscated. Eyes broadly arcuate, a little converging beneath; ocelli large, almost forming a triangle, the posterior separated from each other by a greater distance than they are from the eyes. Clypeus short, transverse, the sides rounded. Head behind very little developed, and almost transverse. Prothorax not much longer than the head; almost transverse behind, not much narrowed in front. Median part of scutellum narrowed

distinctly toward the apex; median segment longer than the mesothorax, depressed in the middle at apex; the laterally produced angles broad, short. Abdominal segments with a broad belt of silvery pruinose pubescence. Legs moderately long; the hinder tibiæ with few spines—longish and black. The transverse basal nervure is not interstitial; for neuration, see pl. III. f. 8.

Length, 7 mm.

Hab. Barrackpore.

From *P. Wroughtoni* which it resembles in colouration it may be known by being stouter, by the head being longer, by the eyes being nearer each other at the top; by the pronotum not having such a gradual slope to the head, and almost transverse behind, by the abdomen being shorter and broader and stouter.

POMPILUS (FERROLA?) ROTHNEYI, *sp. nov.* (Pl. III. f. 9).

Black, pruinose with a plumberous hue, the apex of the abdominal segments broadly black, not pruinose, the pruinosity giving the insect a greyish hue; wings yellowish hyaline, the apex infuscated. Eyes a little converging beneath, ocelli moderate, not in a triangle; the posterior separated from each other by a somewhat greater distance than they are from the eyes. Clypeus equally convex all over, short, broad, the sides obliquely truncated, the apex almost transverse; labrum half the length of the clypeus, bluntly rounded. Occiput transverse, very little developed behind the eyes. Antennæ moderately stout, the scape greyish pruinose. Prothorax longer than the head, not much narrowed towards the head, the sides a little convex, at apex arcuate. Median segment concave at the apex; the sides terminating in stout, somewhat triangular projections, the apex with a thick fringe of pale hair. Abdomen subsessile. Radial cellule short,

broad in the middle, the basal abscissa of the radius a little longer than the second, which is straight, oblique and not curved. The second cubital cellule at the top more than twice the length of the third; at bottom not much longer than it; the third cellule very much narrowed at the top; the transverse cubital nervures being almost united; the first recurrent nervure received quite close to the apex of the wing; the second a little before the middle; it is elbowed in the middle. Legs densely pruinose; the spines long; the long spur of the hind tibiæ reaching before the middle of the metatarsus: the claw with a blunt, thick subapical tooth.

This species forms a transition to *Ferreola*, the apex of the median segment being only moderately concave and hardly dilated at the sides; the antennae, too, are higher up over the clypeus, and the anal nervures in the hind wings are received beyond the cubital. In one example the third cubital cellule is distinctly petiolated.

Length 12 mm.

P. Wroughtoni has the apex of the median segment more as in the typical *Ferreola*, *i.e.*, it is produced laterally, but not quite so much as in, say, *Circe*, it forming, in fact, a regular curve, and it is also depressed in the middle; the abdomen is compressed, the anal nervure in the hind wing is interstitial; the antennæ are placed immediately over the clypeus; the head is very little developed behind the eyes; the basal nervure is not interstitial; the centre of scutellum not much, if any, narrowed towards the apex—the pubescence on the edge of the pronotum forms a whitish band.

POMPILUS WROUGHTONI, *sp. nov.* (Pl. III. f. 10).

Very similar to *P. Rothneyi*, having the same grey pruinose vesture, with the abdominal segments grey and black; and the apex of the median segment concave, the head very

little developed behind the eyes and the abdomen subsessile; but is smaller, narrower, and more slender; the wings are subhyaline throughout, not yellowish or infuscated at the apex; the second cubital cellule is much longer at the bottom compared with the third; the third being of the length of the space bounded by the first transverse cubital and the first recurrent, the latter being received at a greater distance from the transverse cubital; the second recurrent is received in the apical fourth of the cellule, not before the middle, and lastly the long spur of the metatarsus reaches almost close to the apex of the metatarsus.

POMPILUS DELHIENSIS, *sp. nov.* (Pl. III. f. 11).

Black, densely covered with a silvery pubescence, especially thick on the face, median segment and on the apices of the abdominal segments; wings yellow, a broad fuscous band at the radial cellule. Head slightly convex in front, more deeply concave behind. Eyes slightly arcuate at top, at bottom almost parallel; ocelli large, forming almost a triangle; the hinder separated from each other by a greater distance than they are from the eyes. The front with an obscure furrow. Clypeus rounded bluntly and rufous at apex; the centre with a minute incision; mandibles ferruginous, black at top; palpi fuscous. Prothorax a little shorter than the head, the sides slightly convex. Median part of scutellum not much narrowed towards the apex. Median segment shorter than the mesothorax, above with a gentle slope; the apex oblique, with a slight inward curve. Abdomen subsessile; curved, a little longer than the head and thorax united; the segments with a silvery band at the apices: the apical segment acute, shining, impunctate, and bearing a few long blackish hairs. Legs stout, densely pruinose, the tibiæ and tarsi thickly spined; the base of hind tibiæ with a white mark behind. The spurs white, reaching to the middle of

the apex; claws with a narrow subapical tooth. The basal nervure interstitial; the anal nervure in hind wings received before the termination of cubital. (For neuration, see pl III. f. 11.)

Length 9 mm.

Hab. Delhi, (*Rothney*).

Is very nearly related to *P. Rothneyi*, which it also resembles in having the apex of the median segment subconcave; but differs in the wings having the apex hyaline, the cloud not extending to it; the third cubital cellule is much wider at the top, in the radial cellule being longer and much narrower; in the prothorax having the sides convex, in its apex being transverse, not arcuate; in the scutellum being shorter, broader, and not much narrowed towards the apex, and in the white spurs and base of hinder tibiæ, the tarsi, too, being much more thickly spined and fringed beneath.

POMPILUS HERO, *sp. nov.* (Pl. III. f. 12).

Black, densely pruinose, a white belt of pubescence on the pronotum and on the abdominal segments, the metanotum, apex of median segment and base of abdomen tufted with thick greyish hair; the scape yellow beneath; the flagellum ferruginous; the 2-4 tarsal joints white, black at the apex; the edge of pronotum and tegulæ yellowish, wings yellowish-hyaline, infuscated at the apex. Head distinctly convex in front, indistinctly so behind; the clypeus covered with a silvery pubescence, the rest with a short pile and with longish soft pale hairs. Clypeus arcuate in the centre, the sides obliquely truncated. Eyes slightly arcuate at the top, converging a little at the bottom; ocelli separated from each other by a greater distance than they are from the eyes, not forming a triangle. Prothorax shorter than the head, gradually narrowed towards it, behind arcuate. Scutellum gradually narrowed towards the apex. Median

segment shorter than the mesothorax, with a gentle slope, the apex oblique. Abdomen sessile; the apical segment citron-yellow, densely covered with a pale pubescence, and at the apex with longish black hairs. Legs stout; the tibiæ and tarsi with few spines; the claws bifid, the shorter claw much thicker than the other. Antennæ longish, stout, the apical joints dilated beneath. Basal nervure interstitial; the anal in hind wing being received beyond the cubital. (For neuration see pl. III. f. 12). Length 11 mm. ♂. Claws with the basal tooth stout, not reaching to the apex.

In one specimen the hinder tibiæ are whitish-yellow at the base, the spurs being also of this colour.

POMPILUS INCOGNITUS, *sp. nov.* (Pl. III. f. 13).

This species agree in the colouration of the body, legs, and wings with *P. pedestris*, Smith — having the body densely cinereous pruinose, the hind femora and tibiæ red, the wings fusco-hyaline, deeply infuscated at the apex, and the abdomen with cinereous bands; but it must be, I should think, distinct, *e.g.*, although the apex of the median segment is truncated, yet it can hardly be said to be "produced laterally, forming obtuse tubercles"; and the third cubital cellule is called "subtriangular," while here it is distinctly petiolated and not sub-triangular.

Eyes distinctly converging beneath; ocelli separated from the eyes by about the same distance they are from each other. Clypeus a little convex, short, broad; the apex transverse. Head very little developed behind the eyes: the occiput a little concave. Prothorax a little longer than the head, having a gradually rounded slope towards the head, and sub-quadrate behind, arcuate, angled in the middle. Median segment with a slight slope to near the apex, when it becomes oblique; the apex transverse, bearing a thick silvery pubescence; the metapleuræ projecting sharply at the apex into tubercles [this

may be the obtuse tubercles of Smith]. Abdomen elongate, narrow, sessile, longer than the head and thorax united; sharply pointed at the apex, and bearing some long black hairs: the apical segment very smooth and shining. Antennæ shorter than the abdomen, tapering perceptibly towards the apex, not convolute. Wings comparatively short: the radial cellule about twice longer than wide; the radial nervure curved at both ends; second cubital cellule at top half the length of the bottom, where it is a little longer than the third; the third with a petiole as long as three-fourths of the top of the second cubital cellule; the third cellule narrowed at the top, but not forming a triangle, both the nervures being distinctly curved; the first recurrent nervure very oblique and received near the apex of the cellule; the second in the middle. Legs pruinose; the spines long, black; the base of the hind femora and apex of the tibiæ black; the long spur of the hind tibiæ reaches to the middle of the metatarsus. The cloud in the fore wings commences at the apex of the radial cellule.

What is probably a variety has the hind tibiæ black; this form being also smaller.

Length, 12 mm.

POMPILUS VIVAX, *sp. nov.* (Pl. III. f. 14).

Black, pruinose, the scape beneath, the edge of the pronotum and tegulæ yellowish, the face, the scutellum, apex of median segment, coxæ, and base of abdomen densely covered with a thick greyish silvery pubescence; wings subhyaline, the apex infuscated; second cubital cellule petiolate. Eyes a little converging beneath; ocelli in a curve, the hinder separated from the eyes by a distinctly less distance than they are from each other; apex of clypeus in the middle forming a shallow curve; the sides oblique; occiput transverse; the sides rounded. The pubescence below the

antennæ is very dense ; on the front sparser. Prothorax a little longer than the head ; the sides straight, a little narrowed in front, the apex acutely incised against the mesonotum. Median segment with a very gentle slope to the apex which is rounded. Abdomen sessile. Legs long, densely pruinose ; the tibial spine long ; the spurs pale, reaching to near the apex of the metatarsus ; claws bifid. Radial cellule not much longer than deep, narrowed rather sharply in the middle. The first transverse cubital nervure roundly elbowed in the middle, at top three-fourths of the length of the bottom ; second cubital cellule shortly pedunculated, subtriangular ; the first recurrent nervure received near the apex, the second a little beyond the middle. Antennæ stout, the apical joints dilated in the middle ; the scape yellow, joints three and four brownish beneath.

Length, 8 mm.

Hab. Barrackpore (*Rothney*).

POMPILUS VISCHNU, *sp. nov.*

Identical in the colour of the body and wings to *P. vivax* ; differing in the second cubital cellule not being petiolate ; the scutellum and apex of median segment not bearing a dense pubescence ; in the ocelli forming a triangle and the posterior being, if anything, separated from the eyes by a somewhat greater distance than they are from each other ; in the clypeus being rounded ; in the occiput being slightly convex ; in the median segment being widely and deeply furrowed down the centre, in the spurs being shorter (three-fourths of the length of the metatarsus) and black. The abdominal segments have a broad belt of greyish pruinose pubescence on the apex. The legs are pruinose ; the spines short, petiole moderately narrow at the base, becoming gradually wider towards the apex.

Length, 6 mm.

POMPILUS UNIFASCIATUS, *Sm.*

A specimen in Mr. Rothney's collection is thus named by Smith. The type has the head entirely yellow; but this example has a broad black band on the vertex and front. Head convex in front, transverse, with the sides rounded behind. Ocelli almost in a triangle, the posterior separated from the eyes by about the same distance that they are from each other; eyes arcuate above, beneath parallel; clypeus transverse at the apex, the sides obliquely rounded. Prothorax shorter than the head, the sides rounded, narrowing towards the head; behind arcuated, bluntly angled in the centre; there is a furrow in the middle of the pronotum. Legs sparsely spinose; the spines long; the long spur of the hind tibiæ reaches beyond the middle of metatarsus. The second recurrent nervure received in the apical third of the cellule; the anal in hind wing received beyond the termination of the cubital.

POMPILUS ELECTUS, *sp. nov.* (Pl. III. f. 15).

Black; the basal two and the greater part of the third segment red; the greater part of the front and the base of the four posterior tibiæ reddish; the tarsi inclining to fuscous; wings hyaline, a small band along the basal nervure, and a broad one extending from the base of the stigma to the third transverse cubital nervure, fusco-violaceous. Head as broad as the thorax; moderately convex in front, almost transverse behind. Eyes broadly arcuate above, almost diverging below; ocelli hardly forming a triangle, separated from each other by a slightly greater distance than they are from the eyes. Clypeus projecting a little; the sides oblique, straight, the apex bluntly rounded. The head closely punctured; the clypeus and cheeks densely covered with silvery pubescence, the frontal furrow indistinct. Antennæ longish, filiform.

Prothorax shorter than the head; the sides almost straight, not much narrowed towards the head. Median segment short, rather abruptly rounded towards the apex; there is a patch of white silvery hair on either side at the apex. The thorax can hardly be said to be aciculate, and has an olive tinge in parts. Abdomen longer than the head and thorax united, subpetiolate; the apical segment glabrous and impunctate at the base; the rest bearing long hairs and the apex a depressed rufous stiff pile. Legs longish, the hind tibiæ serrate; the long spur of the hind tibiæ reaches to a little beyond the basal third of the metatarsus; the legs densely covered with a silvery pile. Wings longer than the body; radial cellule elongate, narrow, lanceolate at base and apex; the second cubital cellule at top, about one-third longer, at bottom not much longer than it; the first recurrent nervure received beyond the middle, about the same distance that the second is received from the base of the cellule.

Length, 7—8 millim.

The serrated tibiæ are pretty much as in *Priconemis*; but the transverse basal nervure is interstitial, and there is no furrow at the base of abdomen beneath. The wings and antennæ are longer than in any other Indian species known to me from autopsy.

POMPILUS BUDDHA, *sp. nov.* (Pl. III. f. 20).

Black; the abdomen and legs red; the clypeus, inner orbits somewhat widely, and the outer narrowly; three lines on the pronotum (a large central and a somewhat shorter lateral) and two lines on it behind, yellow; wings hyaline, deeply infuscated from the base of the stigma to the apex, which is pale. Eyes almost parallel; ocelli separated from each other by a somewhat greater distance than they are from the eyes. Occiput transverse. Clypeus short, broad, projecting a little, the apex broadly rounded. Prothorax

shorter than the head, the sides rounded. Head and thorax antracous, pruinose. Petiole without a neck, gradually enlarged towards the apex. Antennæ elongate, moderately stout. The radial cellule moderately wide, the apex sharply lanceolate; the first cubital cellule hardly twice longer than the second, the first transverse cubital nervure broadly curved, the second straight; the third elbowed sharply at the middle; the top of the cellule being thus much narrowed; the first recurrent nervure is received in the apical third; the second almost in the middle of the cellule. Legs elongate, pruinose, the tibial spines few; the long spur of the hind tibiæ reaches to the middle of the metatarsus. Claws with a short stout sub-basal tooth.

Length 7-8 mm.

POMPILUS ZEUS, *sp. nov.* (Pl. III. f. 21).

Black; the basal three abdominal segments, the hind femora and tibiæ, the middle femora, except at the base, red; the spines glistening white, wings fusco-hyaline, with fuscous nervures, tegulæ yellowish. Head a little wider than the thorax; eyes very slightly arcuate above, converging beneath; ocelli separated from each other by a distinctly greater distance than they are from the eyes. Clypeus gaping, the sides rounded, the apex almost transverse. Antennæ stout, brownish beneath, the third and fourth joints subequal. Prothorax scarcely so long as the head, the sides straight to the base, behind almost transverse. Median segment somewhat longer than the prothorax; the base with a very gradual slope, the apex much more abrupt; the surface hid by a short close white pubescence. Abdomen longer than the head and thorax united, subsessile; the apical segment impunctate. Legs densely covered with a silvery pile; moderate, the tibiæ and tarsi sparsely spined. The long spur of the hind

tibiæ reaches beyond the middle of the metatarsus. Wings two-thirds of the length of the body. For nervures see Pl. III. fig. 21.

Length, 8 mm.

The third cubital cellule is shorter than in any other Indian species I have seen.

POMPILUS BEATUS, *sp. nov.* (Pl. III. f. 22).

Black, the pronotum with a broad yellow band; the three basal segments of the abdomen, except the apex laterally of the third, red; wings fusco-violaceous. Head small, narrower than the thorax, convex in front, and to a less extent behind. Eyes sharply arcuate at the top, reaching well back behind laterally; converging a little below. Ocelli in a curve, separated from the eyes by a less distance than they are from each other. Head longish from the front view, the clypeus being produced below the eye; its apex transverse. Clypeus and cheeks densely covered with a dense silvery pubescence. A narrow furrow on the front. Prothorax a little longer than the head, broadly arcuate behind, narrowed a little towards the head. Median segment with a gradual slope, and with a transverse ridge at the apex. Abdomen sessile, very gradually and slightly narrowed towards the apex, pruinose; the two apical segments densely covered with silvery pubescence. Legs stout, the hinder tibiæ with the spines of moderate thickness and length; the long spur of the hind tibiæ reaching close to the apex of the metatarsus. Antennæ short, stout, tapering towards the apex. Second cubital cellule sub-petiolate. For neuration see pl. III. fig. 22.

Length, 12 mm.

Hab. Bangalore, South India (*Mus. Cal.*).

POMPILUS VAGABONDUS, *Sm.* (Pl. III. f. 23).

Eyes arcuate above, parallel, not converging beneath. Ocelli in a curve, separated from each other by a greater

distance than they are from the eyes. Clypeus transverse, the sides rounded. Head slightly convex in front. Prothorax shorter than the head, rounded in front. Median segment short, gradually rounded to the apex, not furrowed, obscurely aciculated. Abdomen subsessile; the pygidium elongate, sharply pointed at the apex, longitudinally rugosely striolate. The first transverse cubital nervure slightly curved, oblique; the second and third straight, converging at the top; the second cubital cellule at top and bottom twice the length of the third; both recurrent nervures received towards the apical third of the cellules.

POMPILUS FENESTRATUS, *Smith* (Pl. III. f. 24).

Eyes arcuate, converging a little at the base. Ocelli in a curve, separated by about the same distance from each other that they are from the eyes. Clypeus short, broad, the sides rounded, the apex very slightly arcuate. Head in front convex; the occiput transverse. Prothorax as long as the head, the sides not convex. Median segment aciculated; broadly furrowed down the centre. Abdomen subsessile; pygidium coarsely rugose, covered with long, stiff black hairs. Radial cellule acute in the middle; the third cubital cellule narrowed to a point above, the transverse cubital nervures almost touching there. The first transverse cubital nervure broadly curved; the first recurrent nervure is received a little beyond the middle; the second about the middle.

POMPILUS DETECTUS, *sp. nov.* (Pl. III. f. 25).

Black, the basal two, and the greater part of the third abdominal segment, red; densely pruinose; the wings fusco-violaceous. Eyes arcuate above, slightly converging beneath. Eyes in a triangle, separated from each other by about the same distance they are from the eyes. Clypeus short, subarcuate at the apex. Occiput transverse. Clypeus and

cheeks covered with a dense short whitish pile. Front and vertex obscurely alutaceous. Prothorax a little shorter than the head; and with a rounded slope to the head. Median segment with a gradually-rounded slope to the apex. Abdomen subsessile, as long as the head and thorax united; pruinose, the apical segment coarsely rugose, covered with long bristly stout hairs. Legs stout, the hinder tibiæ with five rows of long stout spines; the long spur of the hinder tibiæ reaches beyond the middle. (For wings see pl. III. fig. 25.) Claws with a short submedian tooth.

POMPILUS LASCIVUS, *sp. nov.* (Pl. III. f. 26).

Black; the head, prothorax, mesonotum, with scutellum and metanotum, red; the wings with the basal half hyaline, the apical fusco-violaceous, except the extreme apex. Head wider than the thorax; the eyes almost parallel; the ocelli hardly forming a triangle; separated from the eyes by a distinctly greater distance than the hinder are from each other. Clypeus convex, the apex rounded. Prothorax shorter than the head, arcuated behind. Median segment with a gradually rounded slope, longer than the prothorax, transversely striolate. Abdomen subsessile, as long as the head and thorax united; with an olive tint, pruinose; the apical segment shining, impunctate. Antennæ stout. Legs stout, the tibiæ sparsely spined; covered with a silvery pubescence; the long spur of the hind tibiæ reaches a little beyond the middle. (For wings see pl. III. f. 26.) The entire body is more or less pruinose; the head and thorax semi-opaque, coarsely aciculate.

Length, 7 mm.

POMPILUS ZEBRA, *sp. nov.* (Pl. III. f. 27).

Black, the mandibles, apex of clypeus, inner orbits of the eyes to near the top broadly, the outer narrowly, a broad band on the pronotum, tegulæ, the abdomen with a

and in the base of the second segment, the third entirely in the three apical, and in the base of the fourth, the apex of the femora broadly, the tibiæ and tarsi and the antennæ ferruginous: the head and thorax bearing long white hairs. Head a little wider than the thorax: the eyes arcuate above, the vertex parallel. Ocelli in a triangle, separated from each other by about the same distance they are from the eyes. Clypeus short, rounded at the apex. Prothorax a little longer than the head, narrowed gradually towards the base. Median segment about as long as the prothorax, gradually rounded to the apex: the apical half bearing a dense covering of white hair. Abdomen semisessile, a little longer than the head and thorax united: its apex moderately acute, the apical segment acicular. Legs densely primrose-hairy: the tibiæ with reddish spines, widely separated: the three middle being the longest: the long white spur of the hind tibiæ reaches beyond the middle of the metatarsus. Claws with a thick basal tooth. There is no apparent sculpture on the body: there is a narrow furrow in the centre of the front, the occiput convex. The stigma is obscure testaceous, the hind wings are only infuscated at the apex.

Length. 10—11 mm.

Hab. Shillong.

POMPILUS PARENTHOPE, *sp. nov.*

Black; the wings fusco-violaceous. Eyes almost parallel. Ocelli separated from the eyes by a distinctly greater distance than they are from each other. Clypeus with the sides rounded; the middle slightly waved and margined. Head moderately well developed behind the eyes; the occiput a little concave. Pronotum hardly so long as the head; the sides rounded. Median segments a little longer than the prothorax, having a gradually rounded slope to the apex; the middle with a wide shallow furrow; aluta-

ceous, covered with a fulvous down. Abdomen shining; the petiole becoming gradually wider towards the apex, so that it is there more than twice the width of the base. Apical segment rugose, thickly covered with stiff hairs; the sides and lower surface with long pale soft hairs. The second cubital cellule at the top more than twice the length of the third; at the bottom equal in length to it; the third at the top about one-third of the length of the bottom; third transverse cubital nervure with a gradual curve to the top; the first recurrent nervure is received near the apex; the second a little beyond the middle. Legs pruinose; the spines sparse; the long joint of the hind tibiæ short, not reaching to the middle of the metatarsus.

Length, 15 mm.

Hab. South-East Provinces.

Planiceps and *Aporus*, distinguished from *Pompilus*, Sensu str., by having only two cubital cellules, are treated by Kohl as sections of Pompilus.

PLANICEPS ORIENTALIS, *sp. nov.* (Pl. III. f. 1).

Black, shining, pruinose; the wings fusco-violaceous, with subhyaline clouds. Clypeus at apex, subarcuate, short, the sides obliquely truncated. Clypeus and cheeks to the antennæ thickly covered with a pale silvery pubescence; the rest of the head, shining, impunctate, very sparsely pilose. Ocelli in a curve, the hinder separated from the eyes by a distinctly less distance than they are from each other; behind them is a longitudinal furrow. Occiput transverse. Prothorax longer than the head, arcuate behind, laterally slightly convex. Median segment short, the base with a moderately rounded slope; the apex oblique. On either side towards the base is a deep semicrescentic short furrow. Abdomen longer than the head and thorax united, subsessile, acutely pointed; the apical segment

shining, impunctate, bearing a few hairs. (For wings see pl. III., fig. 1.) The hind wings subhyaline, smoky at apex. The legs are stout, the two hinder tibiæ and tarsi stoutly spined. Antennæ stout, short, the third joint about one-quarter longer than the fourth.

APORUS COTESI, *sp. nov.* (Pl. III. f. 2).

Black, the scape beneath, palpi, the abdomen, except the two apical segments and the femora beneath, reddish; the tegulæ yellow; wings subhyaline, deeply infuscated from the second transverse cubital nervures. Head transverse behind, the sides rounded; eyes straight, slightly converging beneath; ocelli in a triangle, separated from the eyes by a greater distance than they are from each other; clypeus bluntly rounded at the apex. Vertex and front in the centre shining, almost glabrous; the rest of the face covered with a dense silvery pubescence. Mandibles yellow, piceous at the apex. Occiput transverse. Prothorax nearly as long as the head, angulated in the middle, not semicircular at the apex. Median segments as long as the mesothorax laterally; broadly furrowed down the centre, and having a gradual slope to the apex. The entire thorax covered with a white thick pubescence. Abdomen a little longer than the head and thorax united, subsessile; impunctate, shining, sparsely covered with a pale pubescence. (For wings, see pl. III., f. 2.) Legs moderately long; the tibiæ and tarsi with few spines; the long spur of the hind tibiæ reaching to the middle of metatarsus.

APORUS BENGALENSIS, *sp. nov.*

Black; the head and thorax appearing plumbeous, through being pruinose; the base and apex of the first and the apex of the second with a broad pruinose band; wings subhyaline, infuscated from the second transverse cubital

nervure. Head almost transverse in front, concave behind. Eyes arcuate at top, almost converging at bottom. Ocelli in a triangle, the hinder separated from each other by a distinctly greater space than they are from the eyes. Antennæ longish, brownish underneath. Clypeus convex, almost transverse at the apex in the middle; the sides obliquely rounded. Prothorax a little longer than the head; almost transverse behind; the pleuræ bulging out on the lower side; and excavated broadly behind this bulge; the sides at top straight, not much narrowed till near the head. Median segment longer than the mesothorax, with a gradual slope to the apex; towards the apex with some indistinct waved striæ. Abdomen subsessile. Legs moderately long, the tibiæ with a few spines; the tarsi without them except at the apices of the joints; the long spur of the hind tibiæ reaches a little beyond the middle of the metatarsus. Wings short.

Length, 6 mm.

Apart from colouration, this species is very distinct from *A. cotesi* ♀. The head is concave behind, the collar is longer than the head, the prothorax almost transverse behind; the medium segment distinctly longer than the mesothorax, and the wings are shorter; the apical segment is rugose, densely covered with a stiff reddish pile, and at the apex with some longish hairs. It is a true *Aporus*.

(*Received June 23rd, 1891.*)

To the above are to be added the following, mostly very inadequately, described species of Mr. F. Smith in his posthumous work, "New Species of *Hymenoptera* in the British Museum."

Pompilus clotho, p. 146. Sumatra.

" *lachesis*, p. 146. Sumatra.

Pompilus atropus, p. 146. Sumatra.
" *familiaris*, p. 147. Sumatra.
" *pruniosus*, p. 147. India.
" *capitosus*, p. 147. Burma.
" *mitis*, p. 148. Bombay District.
" *ephippiatus*, p. 148. Bombay District.
" *multifasciatus*, p. 148. Bombay.
" *decoratus*, p. 149. Bombay.
" *similimus*, p. 149. Calcutta.
" *elegans*, p. 150. India.

The following species has been omitted from the alphabetical list:—

HEMIPEPSIS? SYCOPHANTE.

Gribodo, Ann. Mus. Genoa, I., 359.

Hab. Burma.

One of the species belonging to *flava* group.

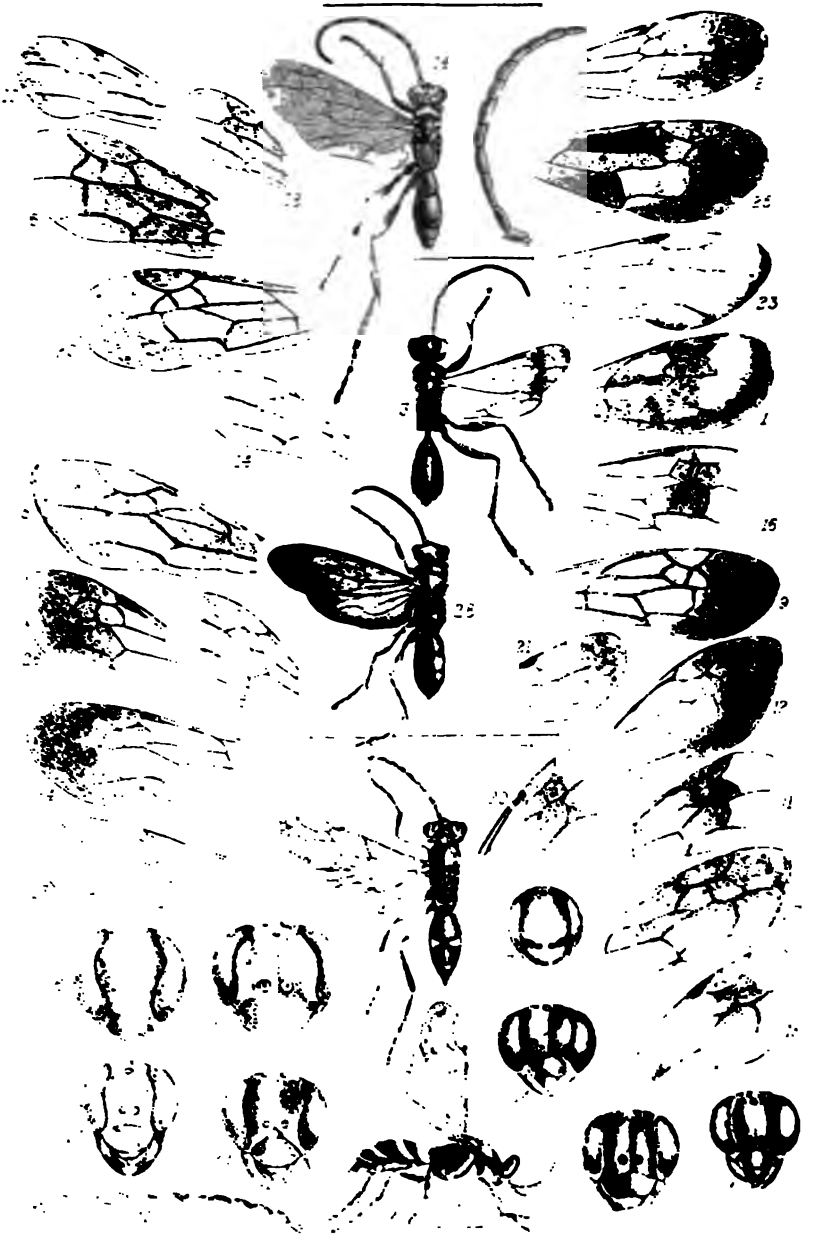
DOLICHURUS.

This genus is usually placed in the *Pompilidæ*, but there can be little doubt but that its true location is with *Ampulex* and *Rhinopsis*.

1. DOLICHURUS TAPROBANÆ.

Smith, *Trans. Ent. Soc.*, 1869, 304.

Hab. Ceylon.



Explanation of Plate.

1. *Planiceps orientalis*, wing.
2. *Aporus ceteri*, wing.
3. *Pseudagenia festinata*, ♀.
4. *Ceropales orientalis*, ♀.
5. *Pompilus circe*, wing.
6. *Do.* *pedalis*, wing.
7. *Do.* *ariadne*, ♀.
8. *Do.* *lunatus*, wing.
9. *Do.* *Rothneyi*, wing and head.
10. *Do.* *Wroughtoni*, wing.
11. *Do* *Dehliensis*, wing.
12. *Do.* *heros*, wing and antenna.
13. *Do.* *inæquitus*, wing.
14. *Do.* *virtus*, wing, head and antenna.
15. *Do.* *electus*, wing.
16. *Do.* *maculipes*, wing.
17. *Do.* *leucopharus*, head.
18. *Do.* *do.* wing.
19. *Salius peregrinus*, ♀.
20. *Pompilus Buddha*, wing.
21. *Do.* *zeus*, wing.
22. *Do.* *beatus*, wing and head.
23. *Do.* *rugabundus*, wing.
24. *Do.* *femoratus*, wing.
25. *Do.* *detectus*, wing.
26. *Do.* *lasciatus*, wing.
27. *Do.* *zebra*, head.
28. *Salius fulvipennis*, ♀.

Annual Report of the Council, 1st April, 1891.

During the past session nine members have resigned, in consequence mainly of removal from the district; three have died, viz., Messrs. C. N. Adams, B.A., John Barrow, F.S.A., and J. P. Holden; and four new members have been elected, leaving 133 members on the roll on the 31st March, 1891, as against 141 at the corresponding period last year.

The accompanying balance sheets set forth the receipts and expenditure of the various accounts, and it will be seen that a balance stands at the credit of each, the total balance in the Society's favour being represented by the cash lying in the hands of the Society's bankers on the 31st March, 1891, viz., £353. 0s. 3d., as against £277. 5s. 10d. at the corresponding period last year. The general balance is, however, larger than it otherwise would have been in consequence of the non-receipt of the usual account for printing the Society's Memoirs, &c.; when this account is passed and paid the balance of £114. 2s. 6d. now standing at the credit of the general account will disappear. This fact, taken in conjunction with the diminished membership and expenses incurred (but not yet discharged) in the recataloguing and rearrangement of the library, brings into prominence the desirableness of increasing the number of members.

The other accounts do not call for any special explanation

The Council recommends the continuance of the system of electing Associates of Sections by the usual annual resolution.

The Librarian reports that during the past year the whole of the Library has been gone through, and the titles

of the books placed on slips, in order that they may be catalogued. The Library has been found to contain 16,700 books, and out of these 2,200 require binding. As far as possible where sets of Transactions, &c., were incomplete, the missing volumes have been obtained. Owing to the rapid increase in the number of books annually received by the Society, it will be necessary in the near future to consider the provision of additional shelving accommodation. Beginning with January 1st of this year a manuscript catalogue for additions to the Library has been started, with slips of all books in the Library placed in alphabetical order and arranged in cases. By this means the books can be easily found by anyone desiring to consult them. Amongst the works presented to the Library by authors or compilers during the year are:—

The Clerk Maxwell Memorial Committee: The Scientific Papers of James Clerk Maxwell, Vols. I., II.; Professor W. G. Farlow: A Provisional Host-Index of the Fungi of the United States, by W. G. Farlow and A. B. Seymour, Part 2; Professor Arthur Cayley, F.R.S., &c.: Collected Mathematical Papers, Vol. III.; Professor M. Foster, F.R.S., &c.: Text-book of Physiology, Part 3; The Canadian Government: Dictionary of the Language of the Micmac Indians, by the Rev. Silas T. Rand, D.D., LL.D.; H. Stopes: Indications of Retrogression in Pre-historic Civilization in the Thames Valley; The Bombay Government: Brief Sketch of the Meteorology of the Bombay Presidency in 1889–90; George Waring Ormerod: Annals of Teignbridge; William Sharp: Experiments with Drugs as a Question of Science; J. F. La Trobe Bateman: History and Description of the Manchester Waterworks; Marquis de Caligny: Académie Royale de Belgique, Four Papers; John Eliot, M.A.: On the Occasional Inversion of the Temperature Relation between the Hills and Plains of Northern India; John Gardiner: Provisional List of the Plants of the Bahama Islands; The Indian Government: Memorandum on the Snowfall in the Mountain Districts of Northern India: Report on the Meteorology of India in 1888; Lothar Meyer: Grundzuge der Theoretischen Chemie; The Mulhouse Hirn Memorial Committee: Manifestation en l'honneur de G. A. Hirn;

Joseph Prestwich, D.C.L., F.R.S.: On the Relation of the Westleton Beds or Pebbly Sands of Suffolk to those of Norfolk, Parts 1, 2, and 3; Jonathan Salt: List of Plants collected chiefly in the neighbourhood of Sheffield; The Victorian Government: Prodromus of the Zoology of Victoria, by Frederick McCoy, Decade I; The Italian Ministry of Public Instruction: Le Opere di Galileo Galilei, Vol. I.; Sir H. E. Roscoe, F.R.S., and C. Schorlemmer, F.R.S.: A Treatise on Chemistry, New Edition, Vol. III., Part 3; Robert Barclay: The Silver Question and the Gold Question; Councillor H. T. Rothwell: Bimetallism.

While the Council considers it advisable to call attention to the fact that the usefulness of the Society is restricted by the comparative narrowness of its financial resources, it has to record that there has been a considerable increase in the number of papers communicated to the Society during the past session, the number being larger than for many years past. The Council rejoices in this gratifying indication of increasing interest in the work of the Society.

Mr. JAMES PLATT HOLDEN, who died on October 20th, at his residence, Smedley Lane, Cheetham, near Manchester, was, at the time of his death, one of the oldest members of the Society, having been elected on January 27th, 1846, under the presidency of Dr. Holme. He was also one of the oldest architects and surveyors in Manchester. He was born in Liverpool, in August, 1806, and served his time as a bricksetter. He subsequently emigrated to the United States, where he worked successively as a bricksetter, builder, and eventually as an architect and surveyor, in partnership with his brother, Isaac. Returning to this country the two brothers began business as architects and surveyors in Manchester, in 1838, but dissolved partnership in 1852, each continuing in practice on his own account. Mr. James P. Holden held the office of surveyor to the Dean and Chapter for about thirty-five years, and of architect to the Cathedral for about twenty-eight years,

during which time a considerable portion of the fabric was restored and the new tower rebuilt. Retiring from practice in 1879, he still retained his connection with the profession through the Manchester Society of Architects, of which he was one of the original members. Though taking little part in the work of the Society, he continued his connection with it until his death, at the ripe age of eighty-five years, and is remembered for the kindliness of his disposition and his readiness to assist others.

Mr. JOHN BARROW, F.S.A., had been a member of the Society since 1867. The bent of his studies lay in chemistry and in natural history, and, except for the last year or two of his life, he was a diligent frequenter of the meetings of the Natural History and Microscopical Section, on the council of which he sat for many years. He was a good field botanist, a patient observer of the phases of growth and the structure of plants, and was distinguished for the assiduity with which he would follow up any special line of research. He was not very ready with his pen and so presented few papers to the Society, but his natural history communications were at times of considerable value. He was specially interested in the medullary rays, and adjacent tissues, as the depositories of starch ; the distribution of the nutritive elements in seeds ; the development of the flower in the *Coniferæ* ; parthenogenesis in the hive-bee ; &c. He took great pains to illustrate any special subject of vegetable physiology, or structure, by employing large series of progressive microscopic sections, which represented the same organ at different parts of the axis, or at different times of the year. In the display of such sections to audiences too large for sitting round a table of microscopes, he manifested considerable ingenuity. In 1869, finding it difficult to describe with precision certain structures which puzzled him, he was led to devise a lantern arrangement by which he could project upon a large screen of finely-ground

shining, impunctate, bearing a few hairs. (For wings see pl. III., fig. 1.) The hind wings subhyaline, smoky at apex. The legs are stout, the two hinder tibiæ and tarsi stoutly spined. Antennæ stout, short, the third joint about one-quarter longer than the fourth.

APORUS COTESI, *sp. nov.* (Pl. III. f. 2).

Black, the scape beneath, palpi, the abdomen, except the two apical segments and the femora beneath, reddish; the tegulæ yellow; wings subhyaline, deeply infuscated from the second transverse cubital nervures. Head transverse behind, the sides rounded; eyes straight, slightly converging beneath; ocelli in a triangle, separated from the eyes by a greater distance than they are from each other; clypeus bluntly rounded at the apex. Vertex and front in the centre shining, almost glabrous; the rest of the face covered with a dense silvery pubescence. Mandibles yellow, piceous at the apex. Occiput transverse. Prothorax nearly as long as the head, angulated in the middle, not semicircular at the apex. Median segments as long as the mesothorax laterally; broadly furrowed down the centre, and having a gradual slope to the apex. The entire thorax covered with a white thick pubescence. Abdomen a little longer than the head and thorax united, subsessile; impunctate, shining, sparsely covered with a pale pubescence. (For wings, see pl. III., f. 2.) Legs moderately long; the tibiæ and tarsi with few spines; the long spur of the hind tibiæ reaching to the middle of metatarsus.

APORUS BENGALENSIS, *sp. nov.*

Black; the head and thorax appearing plumbeous, through being pruinose; the base and apex of the first and the apex of the second with a broad pruinose band; wings subhyaline, infuscated from the second transverse cubital

nervure. Head almost transverse in front, concave behind. Eyes arcuate at top, almost converging at bottom. Ocelli in a triangle, the hinder separated from each other by a distinctly greater space than they are from the eyes. Antennæ longish, brownish underneath. Clypeus convex, almost transverse at the apex in the middle; the sides obliquely rounded. Prothorax a little longer than the head; almost transverse behind; the pleuræ bulging out on the lower side; and excavated broadly behind this bulge; the sides at top straight, not much narrowed till near the head. Median segment longer than the mesothorax, with a gradual slope to the apex; towards the apex with some indistinct waved striæ. Abdomen subsessile. Legs moderately long, the tibiæ with a few spines; the tarsi without them except at the apices of the joints; the long spur of the hind tibiæ reaches a little beyond the middle of the metatarsus. Wings short.

Length, 6 mm.

Apart from colouration, this species is very distinct from *A. cotesi* ♀. The head is concave behind, the collar is longer than the head, the prothorax almost transverse behind; the medium segment distinctly longer than the mesothorax, and the wings are shorter; the apical segment is rugose, densely covered with a stiff reddish pile, and at the apex with some longish hairs. It is a true *Aporus*.

(*Received June 23rd, 1891.*)

To the above are to be added the following, mostly very inadequately, described species of Mr. F. Smith in his posthumous work, "New Species of *Hymenoptera* in the British Museum."

Pompilus clotho, p. 146. Sumatra.
„ *lachesis*, p. 146. Sumatra.

DECEMBER 2nd, 1890.

"General, Morphological and Histological Index to the Author's Collective Memoirs on the Fossil Plants of the Coal Measures. Part I." By William Crawford Williamson, LL.D., F.R.S., &c., Foreign Member of the Royal Swedish Acad. Sc., and of the Royal Society of Göttingen.

"On the *Entomostraca* and *Annelida* in the Levenshulme Mottled Limestones." By Wm. Brockbank, F.L.S., F.G.S.

"On the Specific Heat of Non-Conductors. Part 1: Caoutchouc." By W. W. Haldane Gee, B.Sc., F.C.S., and Hubert L. Terry, F.I.C.

DECEMBER 16th, 1890.

"On Low Temperatures." By Osborne Reynolds, LL.D., F.R.S.

"On the Path of Migratory Birds." By H. H. Howorth, M.P., F.S.A.

"On the Authorship of the Law of Equal Dilation of Gases known on the Continent as that of Gay Lussac, and in England and America as that of Charles." By H. B. Dixon, F.R.S.

"On the Intensity of Transmitted Light when the co-efficient of transmission of the medium is a function of time." By James Bottomley, B.A., D.Sc., F.C.S.

"On the Geological Section exposed by the railway cutting at Levenshulme. Part I." By William Brockbank, F.L.S., F.G.S., and C. E. de Rance, F.G.S.

"On the Action of various Chemical Compounds and Metals on India-rubber." By William Thomson, F.R.S.Ed., F.C.S., and Frederick Lewis.

DECEMBER 30th, 1890.

"Description of *Drosera intermedia* (Hayne), forma *subcaulescens*, with remarks on the Geographical distribution of the family." By James Cosmo Melvill, M.A., F.L.S.

"A New Symbolic Treatment of the Old Logic." By Joseph John Murphy. Communicated by the Rev. Robert Harley, F.R.S., F.R.A.S.

JANUARY 13th, 1891.

"On the late George Waring Ormerod." By C. E. de Rance, F.G.S. Communicated by William Brockbank, F.L.S., F.G.S.

"On the Geological Section exposed in the Levenshulme and Fallowfield railway cutting. Part II." By Wm. Brockbank, F.L.S., F.G.S., and C. E. de Rance, Assoc. Inst. C.E., F.G.S., F.R.G.S., of H.M. Geological Survey.

"On Stereometry." By W. W. Haldane Gee, B.Sc., F.C.S., and Arthur Harden, M.Sc., Ph.D.

JANUARY 27th, 1891.

"On Artificial Flowers from the Canary Islands." By Alderman W. H. Bailey.

FEBRUARY 10th, 1891.

"On deep borings through the Keuper Marls." By C. E. de Rance, F.G.S. Communicated by Wm. Brockbank, F.L.S., F.G.S.

"On the Phenomena of Protective Vaccination and Non-recurrent Disease." By F. J. Faraday, F.L.S.

"On the Source of some Remarkable Boulders in the Isle of Man." By Percy F. Kendall, F.G.S., President of the Stockport Society of Naturalists. Communicated by Thomas Kay, J.P.

FEBRUARY 24th, 1891.

"On the collection of Dirt from the Atmosphere by new belting run at a high speed." By Osborne Reynolds, LL.D., F.R.S.

"On a Harmonic Analyser." By Osborne Reynolds, LL.D., F.R.S.

"Thoughts on Credit Money and on the function of the Precious Metals as Distributors of Wealth. Part I." By F. J. Faraday, F.L.S., F.S.S.

MARCH 10th, 1891.

"On a discovery of *Spirorbis* Limestones near Whitehaven." By William Brockbank, F.L.S., F.G.S.

"On Functions from Groups." By the Rev. Thomas Penyngton Kirkman, M.A., F.R.S.

"Thoughts on Credit Money and on the function of the Precious Metals as Distributors of Wealth. Part II." By F. J. Faraday, F.L.S., F.S.S.

MARCH 24th, 1891.

"Additional Note on the occurrence of the Permians, *Spirorbis* Limestones, and Upper Coal Measures at Frizington Hall, in the Whitehaven District." By William Brockbank, F.L.S., F.G.S.

"Supplementary Note on the *Annelida* and *Entomostraca* in the Levenshulme Limestones." By William Brockbank, F.L.S., F.G.S.

"Historical Account of the genus *Latirus* (Montford) and its dependencies, with descriptions of eleven new species and a catalogue of *Latirus* (Montford) and *Peristernia* (Morch)." By James Cosmo Melvill, M.A., F.L.S.

"On a Method of Comparison of Thermometers." By W. W. H. Gee, B.Sc., F.C.S., and Thomas Ewan, Ph.D., B.Sc.

APRIL 7th, 1891.

"Tables in illustration of the Author's paper on Credit Money and the Precious Metals as Distributors of Wealth." By F. J. Faraday, F.L.S., F.S.S.

APRIL 21st, 1891.

"Note on a new method of estimating Chlorine in Organic Compounds." By Albert Taylor and George Shaw, of the Stockport Technical School. Communicated by Thomas Kay, J.P.

"*Hymenoptera Orientalis.* Part III." By P. Cameron. Communicated by John Boyd.

"On the Occurrence of Permians, *Spirorbis* Limestones and Upper Coal Measures at Frizington Hall, in the Whitehaven District." By William Brockbank, F.L.S., F.G.S.

"On a new species of Fossil Fish, *Strepsodus Brockbanki*, in the Upper Coal Measures of Levenshulme." By James W. Davis, F.G.S., &c. Communicated by William Brockbank, F.L.S., F.G.S.

"On the action of Nitric Acid on Polyterpenes." By Hubert L. Terry, F.I.C. Communicated by W. W. Haldane Gee, B.Sc., F.C.S.

MANCHESTER LITERARY

Charles Bailey, Treasurer, in Account with the

Dr. *Statement of the*

1891.—March 31st:			1890-91. £ s. d.	£ s. d.	1889 £ s. d.
To Cash in hand, 1st April, 1890				277 5 10	
To Members' Contributions :—					
Old Members, 1887-8,	1 Subscription at 42s.		2 2 0		
,, 1888-9,	5 Subscriptions ,, ...		10 10 0		
,, 1889-90,	3 Admission Fees ,, ...		6 6 0		
,, ,,	16 Subscriptions at 42s.		33 12 0		
,, ,,	1 Half-Subscription at 21s. ..		1 1 0		
,, 1890-91,	93 Subscriptions at 42s.		195 6 0		
New Members, ,,	3 Admission Fees at 42s.		6 6 0		
,, ,,	3 Subscriptions ,, ...		6 6 0		
,, 1891-2	1 Subscription ,, ...		2 2 0		
				263 11 0	
To Library Subscriptions :—					
One Natural History Associate at 10s...				0 10 0	
To Contributions from Sections :—					
Microscopical and Natural History Section, 1889-90 ..			0 0 0		5 5 0
Physical and Mathematical Section 1889-90 ..			0 0 0		2 2 0
				0 0 0	
To Use of the Society's Rooms :—					
Manchester Geological Society to 31st March, 1890 ..			0 0 0		30 0 0
Manchester Medical Society to 30th September, 1890 ..			25 0 0		25 0 0
Manchester Photographic Society to 30th Sept., 1890 ..			25 0 0		25 0 0
Manchester Scientific Students' Asso. to 31st Dec., 1890 ..			9 0 0		9 0 0
				59 0 0	
To Sales of the Society's Publications, 1890-1				2 0 5	
To Natural History Fund, 1890-1 :—					
Dividends on £1225, Great Western Railway Co. Stock ..				59 14 4	
To Bank Interest, less Bank Postages, 1890-1				6 18 3	
To Joule Memorial Committee for Postages, &c..				5 1 1	
				£674 0 11	£

1891.—April 1. To Cash in Williams, Deacon, Manchester and Salford Bank, Limited.. .. £

PHILOSOPHICAL SOCIETY.

From 1st April, 1890, to 31st March, 1891, with a Comparative for the Session 1889–1890. **Cr.**

1891—March 31st:—	£ s. d.	1890-91. £ s. d.	£ s. d.	1889-90. £ s. d.
By Charges on Property:—				
Chief Rent (Income Tax deducted)	12 12 0		12 12 0	
Income Tax on Chief Rent	0 6 3		0 6 3	
Insurance against Fire	13 17 6		13 17 6	
Repairs, &c.	4 8 2		8 10 3	
Cases for Dalton Apparatus	0 0 0		24 14 0	
By House Expenditure:—		31 3 11		60 0 0
Coal, Gas, Candles, Water, &c.	34 6 5		33 6 9	
Tea, Coffee, &c., at Meetings	12 7 1		13 16 7	
Cleaning, Brushes, &c.	5 9 1		6 12 2	
By Administrative Charges:—		52 2 7		53 15 6
Clerk and Housekeeper	62 8 0		62 8 0	
Postages and Carriage of Parcels	26 8 6		27 1 11	
Stationery, Printing Circulars, Receipts, and Engrossing	6 2 4		11 15 11	
Distributing 'Memoirs'	0 0 0		6 7 9	
By Publishing:—		94 18 10		107 13 7
Honorarium for editing the Society's publications	50 0 0		50 0 0	
Printing and Binding 'Memoirs and Proceedings,' new series	0 0 0		80 3 0	
Wood Engraving and Lithography	30 2 6		31 19 8	
By Library;—		80 2 6		162 2 8
Binding Books in Library	0 0 0		52 2 8	
Books and Periodicals	19 15 5		14 18 1	
Assistant in Library	10 0 0		8 10 0	
Palæontographical Society for the year 1890	0 0 0		1 1 0	
Ray Society for the year 1890	0 0 0		1 1 0	
Zoological Record, Vol. 26	1 0 0		1 0 0	
By Natural History Fund:—		30 15 5		78 12 9
Works on Natural History	21 18 11		18 11 2	
Grant to Microscopical and Natural History Section	0 0 0		50 0 0	
Plates for Natural History Papers in 'Memoirs'	9 18 6		.. .. ..	
		31 17 5		68 11 2
By Balance 31st March, 1891		353 0 3		277 5 10
		£674 0 11		£808 1 6

NOTE.—The Accounts (of which the above is a summary) have been audited, and found correct, by Mr. Francis Jones, F.R.S.E., F.C.S., and Mr. Samuel Okell, F.R.A.S.

Summary Balance Sheet, Session 1890–1.

	£ s. d.	£ s. d.
General Account :—		
Balance in favour of this Account, 1st April, 1890.. .. .. .. £66 5 0		
Receipts during the Session, 1890-1, Ordinary 331 19 8		
,, ,, Joule Memorial Committee .. 5 1 1		
	403 5 9	
Expenditure during the Session, 1890-1	289 3 3	
Balance in favour of this Account, 31st March, 1891		114 2 6
Compounders' Fund :—		
Balance in favour of this Account, 1st April, 1890	177 10 0	
Balance in favour of this Account, 31st March, 1891	.. ..	177 10
Natural History Fund :—		
Balance in favour of this Account, 1st April, 1890 .. .. .. £33 10 10		
Dividends on Gt. Western Railway Co.'s Stock during the Session 1890-1 £59 14 4		
	93 5 2	
Expenditure during the Session 1890-1	31 17 5	
Balance in favour of this Account, 31st March, 1891		61 7 9
Cash in Williams, Deacon, and Manchester and Salford Bank, Limited, 31st March, 1891 ..		£353 0 3

Annual Report of the Council of the Microscopical and Natural History Section.

The usual monthly meetings of the Section have been held during the session, and the attendance has been fairly maintained. Several important papers have been contributed, notably Mr. J. COSMO MELVILL'S on *Drosera intermedia*, var. *subcaulescens*, and on the genus *Latirus*, with descriptions of eleven new species, and Mr. P. CAMERON'S third part of his *Hymenoptera Orientalis*, which are being printed in extenso in the Society's *Memoirs and Proceedings*. Very interesting exhibits have also been made at all the meetings.

Our numbers, however, it will be noted, have fallen off somewhat. One of our oldest members, Mr. JOHN BARROW, died in October, three members and four associates have resigned, being no longer able to attend our meetings, and we have only elected one new member and one new associate.

It is, therefore, much to be desired that steps should be taken to enrol a number of new members and associates in our ranks. It is felt that, if the advantages the Section offers were only better known, there are a number of naturalists and others, in Manchester and the neighbourhood, who would be glad to join us.

The following is a list of members and associates of the Section :—

Members :—J. J. ASHWORTH, CHAS. BAILEY, F.L.S., JOHN BOYD, HENRY BROGDEN, F.G.S., ALFRED BROWN, M.D., SAMUEL COTTAM, F.R.A.S., EDWARD COWARD, ROBERT ELLIS CUNLIFFE, R. D. DARBISHIRE, B.A., F.G.S., Prof. W. BOYD DAWKINS, M.A., F.R.S., F.G.S., HASTINGS C. DENT, F.L.S., W. K. DEANE, FREDERICK JAS. FARADAY, F.L.S., CHAS. JAMES HEYWOOD, ALEX.

HODGKINSON, B.Sc., M.B., J. ARTHUR HUTTON, HENRY HOYLE HOWORTH, F.S.A., M.P., Prof. A. MILNES MARSHALL, M.A., M.D., D.Sc., F.R.S., J. COSMO MELVILL, M.A., F.L.S., J. E. MORGAN, M.D., M.A., FRANCIS NICHOLSON, F.Z.S., EDMUND SALIS SCHWABE, B.A., J. TATHAM, M.A., M.D., Prof. W. C. WILLIAMSON, LL.D., F.R.S., JOHN DODGSHON.

Associates:—WILLIAM BLACKBURN, F.R.M.S., E. S. BLES, M.B., PETER CAMERON, HERBERT C. CHADWICK, E. PYEMONT COLLETT, PETER CUNLIFFE, F. R. CURTIS, H. L. EARL, B.A., JOHN RAY HARDY, ARNOLD V. HENN, FRANK HUET, L.D.S., R.C.S., HENRY HYDE, LESLIE JONES, M.D., H. L. KNOOP, J. B. PETTIGREW, THOMAS ROGERS, GEORGE NASH SKIPP, MARK STIRRUP, F.G.S., THEODORE SINGTON, W. LADD TORRANCE, EDWARD WARD, F.R.M.S., W. R. SCOWCROFT.

Total 25 members and 22 associates, against 27 members and 27 associates at the corresponding period of last year.

The Microscopical and Natural History Section of the Manchester Literary and Philosophical Society in account with the Parent Society for Grant from the Natural History Fund.

Dr. *From March 31st 1890, to April 16th, 1891.* **Cr.**

1890.		£ s. d.	1890.		£ s. d.
	To Balance of Grant unexpended	38 9 11	Aug. 2.	By Fauna and Flora, d. Golfes v. Neapel, vol. 9	3 0 6
			1890-91.	„ Fowler's Coleoptera, 8 Parts, 40-47	1 13 4
				„ Balance.....	33 16 1
		£38 9 11			£38 9 11
	To Balance of Grant unexpended	£33 16 1			

Mark Stirrup, Treasurer, in account with the Microscopical and Natural History Section of the Manchester Literary and Philosophical Society.

Dr. *Session 1890-91.* **Cr.**

1890.		£ s. d.	1890.		£ s. d.
Dec. 20.	To Balance in Manchester and Salford Bank (St. Ann Street Branch)	95 7 2	July 31.	By J. E. Cornish, "Naturalist, Micro. Journal," &c.	1 16 4
	„ Bank Interest	1 19 9	Aug. 2.	„ Williams and Norgate, "Fauna and Flora G. v. Neapel"	3 0 6
	„ Subscriptions and Arrears from March 28th, 1890, to April 16th, 1891	27 10 0	Dec. 4.	„ West Newman and Co., "Journal of Botany, 1890"	0 12 0
			„	„ J. E. Cornish, "Fowler's Coleoptera & Naturalist"	0 9 5
			„	„ Charles Simms and Co., Circulars and Cards	0 14 0
			1891.		
			Jun 10.	„ Gurney and Jackson, "Ibis 1891"	1 1 0
			„	„ Thos. Armstrong and Bro., Stand Condenser	0 19 0
			Mar. 18.	„ Charles Simms and Co., Circulars	1 13 0
			24.	„ J. E. Cornish, "Fowler's Coleoptera & Naturalist"	0 13 9
			Apl. 7.	„ Parent Society, Sectional Subscription	5 5 0
			14.	„ Chas. Hargreaves— Teas .....£2. 14s. 0d. Postages, &c., £1. 3s. 11d.	3 17 11
			16.	„ J. E. Cornish, "Fowler's Coleoptera"	0 4 2
			„	„ Do., "Naturalist," January to March	0 1 3
				By Balance in Manchester and Salford Bank (St. Ann Street Branch) 104 9 7	
		£124 16 11			£124 16 11
	To Balance to Credit of Section.....	£104 9 7			

24th April, 1891.
Examined and found correct,
GEO. NASH SKIPP,
W. R. SCOWCROFT.

THE COUNCIL AND MEMBERS.

APRIL 21, 1891.

President.

EDWARD SCHUNCK, PH.D., F.R.S., F.C.S.

Vice-Presidents.

WILLIAM CRAWFORD WILLIAMSON, LL.D., F.R.S.,
FOREIGN MEMBER OF THE ROYAL SWEDISH ACAD. SC., AND OF THE ROYAL SOCIETY OF GÖTTINGEN.

OSBORNE REYNOLDS, M.A., LL.D., F.R.S.

ARTHUR SCHUSTER, PH.D., F.R.S., F.R.A.S.

JAMES BOTTOMLEY, B.A., D.Sc., F.C.S.

Secretaries.

FREDERICK JAMES FARADAY, F.L.S., F.S.S.

REGINALD F. GWYTHER, M.A.

Treasurer.

CHARLES BAILEY, F.L.S.

Librarian.

FRANCIS NICHOLSON, F.Z.S.

Of the Council.

JOHN BOYD.

HAROLD B. DIXON, M.A., F.R.S.

WILLIAM HENRY JOHNSON, B.Sc.

JAMES COSMO MELVILL, M.A., F.L.S.

ALEXANDER HODGKINSON, M.B., B.Sc.

J. W. F. TATHAM, M.A., M.D.

HONORARY MEMBERS.

Date of Election.

1847, April 20. Adams, John Couch, LL.D., F.R.S., V.P.R.A.S., F.C.P.S., Director of the Observatory, and Lowndsean Prof. of Astron. and Geom. in the Univ. of Cambridge. Cor. Mem. Inst. Fr. (Acad. Sci.), &c. *The Observatory, Cambridge.*

1843, April 18. Airy, Sir George Biddell, K.C.B., M.A., D.C.L., LL.D., Hon. Mem. R.S.E., R.I.A., F.C.P.S., For. Mem. Inst. Fr. (Acad. Sci.), &c. *The White House, Croom's Hill, Greenwich Park, S.E.*

1887, April 19. Armstrong, Sir Wm. George, C.B., D.C.L., LL.D. *Newcastle-on-Tyne.*

1886, Feb. 9. Baker, Sir Benjamin, LL.D., M. Inst. C.E. 2, *Queen's Square Place, Westminster, S.W.*

1886, Feb. 9. Baker, John Gilbert, F.R.S. *Kew.*

1886, Feb. 9. Berthelot, Prof. Marcellin, For. Mem. R.S., Membre de l'Institut. *Paris.*

1886, Feb. 9. Buchan, Alexander, F.R.S.E. 72, *Northumberland Street, Edinburgh.*

1860, April 17. Bunsen, Robert Wilhelm, Ph.D., For. Mem. R.S., Prof. of Chemistry at the Univ. of Heildelberg. *Heidelberg.*

1888, April 17. Cannizzaro, S., Prof. of Chemistry. *University of Rome.*

1889, April 30. Carruthers, William, Pres. L.S., F.R.S. Keeper of Botanical Dept., British Museum.

1859, Jan. 25. Cayley, Arthur, M.A., LL.D., D.C.L., V.P.R.A.S., F.C.P.S., Sadlerian Prof. of Pure Maths. in the Univ. of Cambridge, Cor. Mem. Inst. Fr. (Acad. Sci.), &c. *Garden House, Cambridge.*

1886, Oct. 30. Clifton, Robert Bellamy, M.A., F.R.S., F.R.A.S., Prof. of Natural Philosophy, Oxford. *New Museum, Oxford.*

1889, April 30. Cohn, Ferdinand, Professor of Botany. 26, *Schweidnitzer Stadtgraben, Breslau.*

1887, April 19. Cornu, Professor Alfred, For. Mem. R.S., Membre de l'Institut. *Ecole Polytechnique, Paris.*

1886, Feb. 9. Dawson, Sir John William, C.M.G., M.A., F.R.S., LL.D., F.G.S. *McGill College, Montreal.*

1888, April 17. Dewalque, Gustave, Professor of Geology. *University of Liège.*

1889, April 30. Farlow, W. G., Professor of Botany. *Harvard College, Cambridge, Mass., U.S.A.*

Date of Election.

1889, April 30. Flower, William Henry, C.B., LL.D., F.R.S. Director of Nat. Hist. Dept., British Museum.

1889, April 30. Foster, Michael, M.A., M.D., LL.D., Sec. R.S., Professor of Physiology. *Trinity College, Cambridge.*

1860, Mar. 9. Frankland, Edward, Ph.D., M.D., LL.D., D.C.L., V.P.C.S., F.R.S., Cor. Mem. Inst. Fr. (Acad. Sci.). &c. *The Yews, Reigate Hill, Reigate.*

1889, April 30. Hertz, H., Professor of Physics. *Bonn.*

1848, Jan. 25. Hind, John Russell, LL.D., F.R.S., F.R.A.S., Superintendent of the Nautical Almanac. Cor. Mem. Inst. Fr. (Acad. Sci.) 3, *Cambridge Park Gardens, Twickenham.*

1881, April 17. Hittorf, Johann Wilhelm, Professor of Physics. *Polytechnicum, Münster.*

1886, Feb. 9. Helmholtz, Geheimrath Herman von, LL.D., For. Mem. R.S. Präsident der Physikalisch-technischen Reichsanstalt. *Berlin.*

1866, Jan. 23. Hofman, A. W., Ph.D., M.D., LL.D., F.R.S., Cor. Mem. Inst. Fr. (Acad. Sci.), &c. 10, *Dorotheenstrasse, Berlin.*

1869, Jan. 12. Huggins, William, LL.D., D.C.L., F.R.S., F.R.A.S., Cor. Mem. Inst. Fr. (Acad. Sci.). 90, *Upper Tulse Hill, Brixton, London, S.W.*

1872, April 30. Huxley, Thomas Henry, M.D., Ph.D., LL.D., D.C.L., P.P.R.S., Hon. Prof. of Biology in Royal School of Mines, Cor. Mem. Inst. Fr. (Acad. Sci.), &c. 4, *Marlborough Place, Abbey Road, N.W.*

1852, Oct. 16. Kirkman, Rev. Thomas Penyngton, M.A., F.R.S., *Croft Rectory, near Warrington.*

1886, Feb. 9. Kopp, Prof. Hermann. *Heidelberg.*

1887, April 19. Langley, Prof. S. P., *Alleghany Observatory, Pittsburg, U.S.*

1887, April 19. Laveleye, Emile de, *Liège University.*

1887, April 19. Lockyer, Norman, F.R.S., Cor. Mem. Inst. Fr. (Acad. Sci.). *Science School, Kensington.*

1889, April 30. Lubbock, Sir John, Bart., M.P., D.C.L., LL.D., F.R.S. 15, *Lombard Street, E.C.*

1889, April 30. Mendeléeff, D., Professor of Chemistry. *St. Petersburg.*

1889, April 30. Meyer, Lothar, Professor of Chemistry. *Tübingen.*

1887, April 19. Newcomb, Prof. Simon, For. Mem. R.S. *Johns Hopkins University, Baltimore, U.S.*

1844, April 30. Owen, Sir Richard, K.C.B., M.D., LL.D., F.R.S., F.L.S., F.G.S., V.P.Z.S., F.R.C.S., Ireland, Hon. M.R.S.E., For. Assoc. Inst. Fr. (Acad. Sci.), &c. *Sheen Lodge, Richmond.*

Date of Election.

1866, Feb. 9. Pasteur, Louis, For. Mem. R.S., Membre de l'Institut. *Paris.*

1851, April 29. Playfair, Rt. Hon. Sir Lyon, K.C.B., LL.D., Ph.D., F.R.S., F.G.S., M.P., V.P.C.S., &c. 68, *Onslow Gardens, London, S.W.*

1866, Jan. 23. Prestwich, Joseph, F.R.S., F.G.S., Cor. Mem. Inst. Fr. (Acad. Sci.) *Shoreham, near Sevenoaks.*

1866, Jan. 23. Ramsay, Sir Andrew Crombie, LL.D., F.R.S., F.G.S., 15, *Cromwell Crescent, South Kensington, London.*

1849, Jan. 23. Rawson, Robert, F.R.A.S. *Havant, Hants.*

1866, Feb. 9. Rayleigh, John William Strutt, Lord, M.A., D.C.L., (Oxon.), LL.D., (Univ. McGill), Sec. R.S., F.R.A.S. *Tirling Place, Witham, Essex.*

1887, April 19. Römer, Dr. Fred. *Breslau.*

1889, April 30. Résal, Professor Henri, Membre de l'Institut. *Ecole Polytechnique, Paris.*

1889, April 30. Roscher, Dr. Wilhelm, K. Geheimer Rath, and Professor of Political Economy. *Leipsic.*

1889, April 30. Routh, Edward John, Sc.D., F.R.S. *Newnham Cottage, Cambridge.*

1872, April 30. Sachs, Julius von, Ph.D. *Würzburg.*

1889, April 30. Salmon, Revd. George, D.D., D.C.L., LL.D., F.R.S., Regius Professor of Divinity. *Provost's House, Trinity College, Dublin.*

1889, April 30. Siemens, Dr. Ernst Werner von, Geheimer Rath. 94, *Markgrafenstrasse, Berlin.*

1869, Dec. 14. Sorby, Henry Clifton, LL.D., F.R.S., F.G.S., &c. *Broomfield, Sheffield.*

1851, April 29. Stokes, Sir George Gabriel, Bart., M.A., M.P., LL.D., D.C.L., Pres. R.S., Lucasian Professor of Mathem. Univ. Cambridge, F.C.P.S., Cor. Mem. Inst. Fr. (Acad. Sci.), &c. *Lensfield Cottage, Cambridge.*

1886, Feb. 9. Strasburger, Professor. *Bonn.*

1861, Jan. 22. Sylvester, James Joseph, M.A., D.C.L., LL.D., F.R.S. Savilian Prof. of Geom. in the Univ. of Oxford, Cor. Mem. Inst. Fr. (Acad. Sci.), &c. *New College, Oxford.*

18[illegible], April 28. Tait, Peter Guthrie, M.A., F.R.S.E., &c., Professor of Natural Philosophy, Edinburgh. 38, *George Square, Edinburgh.*

1851, April 22 Thomson, Sir William, M.A., D.C.L., LL.D., F.R.S.S.L. and E. Prof. of Nat. Phil. in Univ. of Glasgow. For Assoc. Inst. Fr. (Acad. Sci.), 2, *College, Glasgow.*

1872, April 30. Trécul, A., Member of the Institute of France. *Paris.*

1886, Feb. 9. Tylor, Edward Burnett, F.R.S., D.C.L. (Oxon), LL.D. (St. And. and McGill Colls.), Keeper of University Museum. *Oxford.*

Date of Election.

1868, April 28. Tyndall, John, LL.D., M.D., D.C.L., Ph.D., F.R.S., F.C.S. *Hind Head House, Haslemere, London, W.*

1889, April 30. Williamson, Alexander William, Ph.D., LL.D., For. Sec. R.S., Corr. Mem. Inst. Fr. (Acad. Sci.). *High Pitfold, Shottermill, Haslemere.*

1886, Feb. 9. Young, Prof. C. A. *Princeton College, N.J., U.S.*

1888, April 17. Zirkel, Ferdinand, Professor of Mineralogy. *University of Leipsic.*

CORRESPONDING MEMBERS.

Date of Election.

1860, April 17. Ainsworth, Thomas. *Cleator Mills, near Egremont, Whitehaven.*

1870, March 8. Cockle, The Hon. Sir James, M.A., F.R.S., F.R.A.S., F.C.P.S. 12, *St. Stephen's Road, Bayswater, London.*

1866, Jan. 23. De Caligny, Anatole, Marquis, Corresp. Mem. Acadd. Sc. Turin and Caen, Socc. Agr. Lyons. Sci. Cherbourg, Liège, &c.

1861, April 2. Durand-Fardel, Max, M.D., Chev. of the Legion of Honour, &c. 36, *Rue de Lille, Paris.*

1849, April. 17. Girardin, J., Off. Legion of Honour, Corr. Mem. Institt. France, &c. *Lille.*

1850, April 30. Harley, Rev. Robert, F.R.S., F.R.A.S. 17, *Wellington Square, Oxford.*

1882, Nov. 14. Herford, Rev. Brooke. *Arlington Street, Boston, U.S.*

1862, Jan. 7. Lancia di Brolo, Frederico, Duc, Inspector of Studies, &c. *Palermo.*

1859, Jan. 25. Le Jolis, Auguste-François, Ph.D. Archiviste perpétuel and late president of the Soc. Nat. Sc. Cherbourg, &c. *Cherbourg.*

1857, Jan. 27. Lowe, Edward Joseph, F.R.S., F.R.A.S., F.G.S., Mem. Brit. Met. Soc., &c. *Shirenewton Hall, near Chepstow.*

1869, Feb. 5. Schönfield, Edward, Ph.D., Director of the Mannheim Observatory.

ORDINARY MEMBERS.

Dat of Election.

1873, Jan. 7. Allmann, Julius. 70, *Deansgate.*

1870, Dec. 13. Angell, John, F.C.S., F.I.C. 6, *Beacons-Field, Derby Road, Fallowfield.*

1861, Jan. 22. Anson, Ven. Archd. George Henry Greville, M.A., *Birch Rectory, Rusholme.*

1885, Nov. 17. Armstrong, Thomas, F.R.M.S. *Brookfield, Urmston; Deansgate.*

1837, Aug. 11. Ashton, Thomas. 36, *Charlotte Street,*

1881, Nov. 1. Ashton Thomas Gair, M.A. 36, *Charlotte Street.*

1887, Nov. 16. Ashworth, J. Jackson. 39, *Spring Gardens, City.*

1865, Nov. 15. Bailey, Charles, F.L.S. *Ashfield, College Road, Whalley Range, Manchester.*

1888, Nov. 13. Bailey, G. H., D.Sc., Ph.D. *The Owens College.*

1888, Feb. 7. Bailey, Alderman W. H. *Summerfield, Eccles New Road.*

1876, Nov. 28. Barratt, Walter Edward. *Kersal, Higher Broughton.*

1889, Jan. 8. Beard, J. R. *Richmond Grove, Longsight.*

1868, Dec. 15. Bickham, Spencer H. *Oakwood, Alderley Edge.*

1861, Jan. 22. Bottomley, James, D.Sc., B.A., F.C.S. 220, *Lower Broughton Road.*

1889, Jan. 22. Bowman, George, M.D. *Monifieth, Stretford Road, Old Trafford.*

1875, Nov. 16. Boyd John. *Barton House, Didsbury Park, Didsbury.*

1889, Oct. 15. Bradley, Nathaniel. 65, *Mosley Street, City.*

1855, April 17. Brocklank, William, F.G.S., F.L.S. *Chapel Walks.*

1861, April 2. Brogden, Henry, F.G.S. *Hale Lodge, Altrincham.*

1844, Jan. 22. Brooks, Sir William Cunliffe, Bart., M.A., M.P. *Bank,* 92, *King Street.*

1889, April 16. Brooks, Herbert S. *Slade House, Levenshulme.*

1860, Jan. 23. Brothers, Alfred F.R.A.S. 12, *Swinton Avenue.*

1886, April 6. Brown, Alfred, M.A., M.B. *Claremont, Higher Broughton.*

1846, Jan. 27. Browne, Henry, M.A. (Glas.), M.R.C.S. (Lond.), M.D. (Lond.). *Heaton Mersey.*

1889, Jan. 8. Brownell, T. W. *School Board Offices, Deansgate.*

1880 Oct. 15. Budenberg, C. F., M.Sc. 25, *Demesne Road, Alexandra Road.*

1872, Nov. 12. Burghardt, Charles Anthony, Ph.D. 35, *Fountain Street.*

1891. April 21. Buxton, John H. *Guardian Office,* 3, *Cross Street.*

1854, April 18. Christie, Richard Copley, M.A., Chancellor of the Diocese, *The Elms, Rochampton, S.W.*

1841, April 30. Clay, Charles, M.D., Extr. L.R.C.P. (Lond.), M.R.C.S. (Edin.). *Tower Lodge, Poulton-le-Fylde, Lanc.*

Date of Election.

1886, Dec. 14. Cohen, J. B., Ph.D. *The Owens College.*

1884, Nov. 4. Corbett, Joseph. 9, *Albert Square.*

1853, Jan. 25. Cottam, Samuel, F.R.A.S., F.R. Hist. S., F.C.A. 49, *Spring Gardens.*

1859, Jan. 25. Coward, Edward. *Heaton Mersey, near Manchester.*

1861, Nov. 12. Coward, Thomas. *Higher Downs, Altrincham.*

1849, Jan. 25. Crowther, Joseph Stretch. *Endsleigh, Alderley Edge.*

1876, April 18. Cunliffe, Robert Ellis. *Halton Bank, Pendleton.*

1871, Nov. 8. Dale, Richard Samuel, B.A., 1, *Chester Terrace, Chester Road.*

1853, April 19. Darbishire, Robert Dukinfield, B.A., F.S.A., F.G.S., 26, *George Street.*

1878, Nov. 26. Davis, Joseph. *Engineer's Offices, Lancashire and Yorkshire Railway, Hunt's Bank.*

1869, Nov. 2. Dawkins, William Boyd, M.A., F.R.S., F.G.S., F.R.S., Assoc. Inst. C.E., Hon. Fellow Jesus College, Oxford; Professor of Geology in Owens College. *The Owens College.*

1861, Dec. 10. Deane, William King. *Almondbury Place, Chester Road.*

1879, Mar. 18. Dent, Hastings Charles, F.L.S., F.R.G.S. 20, *Thurloe Square, London, S.W.*

1878, Feb. 8. Dixon, Harold B., M.A., F.R.S., Professor of Chemistry, *The Owens College.*

1886, Mar. 9. Dodgshon, John. *Moorside, Davenport, Stockport.*

1883, Oct. 2. Faraday, Frederick James, F.L.S., F.S.S. *Ramsay Lodge, Slade Lane, Levenshulme.*

1886, Feb. 9. Gee, W. W. Haldane, B.Sc. *The Owens College.*

1881, Nov. 1. Greg, Arthur. *Eagley, near Bolton.*

1874, Nov. 3. Grimshaw, Harry, F.C.S. *Thornton View, Clayton.*

1888. Feb. 7. Grimshaw, William. *Stoneleigh, Sale.*

1875, Feb. 9. Gwyther, R. F., M.A., Fielden Lecturer in Mathematics, Owens College. *The Owens College.*

1889, Nov. 12. Hadley, H. E. *The Owens College.*

1889, Nov. 12. Hall, Charles John, Mus. Doc. *Hawkesmoor, Southport.*

1890, Feb. 18. Harker, Thomas. *Brook House, Fallowfield.*

1890, Jan. 7. Harrison, Fred., B.A. *The Grammar School.*

1862, Nov. 4. Hart, Peter. *Messrs. Tennants & Co., Mill Street, Clayton N., Manchester.*

1873, Dec. 16. Heelis, James. 71, *Princess Street.*

1890, Mar. 4. Henderson, H. A. 60, *Upper Jackson Street, Hulme.*

1890, Nov. 4. Heenan, R. H., Engineer, *Chapel Walks.*

1828, Oct. 31. Henry, William Charles, M.D., F.R.S. *Hatfield, near Ledbury, Herefordshire.*

1889, Jan. 8. Heywood, Charles J. *Chaseley, Pendleton.*

Date of Election.

1833, April 26. Heywood, James, F.R.S., F.G.S., F.S.A. 26, *Kensington Palace Gardens, London, W.*

1864, Mar. 22. Heywood, Oliver. *Bank, St. Ann's Street.*

1884, Jan. 8. Hodgkinson, Alexander, M.B., B.Sc. 18, *St. John Street.*

1882, Oct. 17. Holt, Henry. *The Cedars, Didsbury.*

1873, Dec. 2. Howorth, Henry H., F.S.A., M.P. *Bentcliffe House, Eccles.*

1889, Oct. 15. Hoyle, W. E., M.A., Keeper of the Manchester Museum. 25, *Brunswick Road, Withington.*

1884, Jan. 8. Hurst, Charles Herbert. *Rosney, Brighton Grove, Rusholme.*

1888, April 17. Hutton, James Arthur. 29, *Church Street, City.*

1870, Nov. 1. Johnson, William H., B.Sc. 26, *Lever Street.*

1878, Nov. 26. Jones, Francis, F.R.S.E., F.C.S. *Grammar School.*

1890, Jan. 7. Joseland, H. L., B.A. *The Grammar School.*

1886, Jan. 12. Kay, Thomas, J.P. *Moorfield, Stockport.*

1852, Jan. 27. Kennedy, John Lawson. 47, *Mosley Street.*

1890, Nov. 4. Langdon, Maurice Julius, Ph.D., Chemist. *Sunbury, Victoria Park.*

1863, Dec. 15. Leake, Robert, M.P. *The Dales, Whitefield.*

1884, April 15. Leech, Daniel John, Professor, M.D. *The Owens College.*

1850, April 30. Leese, Joseph. *Messrs. S. & E. Leese, Fylde Road Mill, Preston.*

1857, Jan. 27. Longridge, Robert Bewick. *Yew Tree House, Tabley, Knutsford.*

1870, April 19. Lowe, Charles, F.C.S. *Summerfield House, Reddish, Stockport.*

1866, Nov. 13. McDougall, Arthur, B.Sc. *Clifton Lodge, Gore Street, Greenheys.*

1859, Jan. 25. Maclure, John William, M.P., F.R.G.S. *Whalley Range.*

1875, Jan. 26. Mann, John Dixon, M.D., M.R.C.P., Lond. 16, *St. John Street.*

1879, Dec. 2. Marshall, Arthur Milnes, M.A., M.D., D.Sc., F.R.S., Professor of Zoology, Owens College. *The Owens College.*

1864, Nov. 1. Mather, William, M.P. *Iron Works, Salford.*

1873, Mar. 18. Melvill, James Cosmo, M.A., F.L.S. *Kersal Cottage, Prestwich.*

1879, Dec. 30. Millar, John Bell, M.E., Assistant Lecturer in Engineering, Owens College. *The Owens College.*

1881, Oct. 18. Mond, Ludwig, F.C.S. *Winnington Hall, Northwich.*

1861, Oct. 29. Morgan, John Edward, M.D., M.A., F.R.C.P., Lond., F.R. Med. and Chir. S., Professor of Medicine in the Victoria University. 1, *St. Peter's Square.*

Date of Election.	
1880, April 26.	Monkhrie, George W.
1873, Mar. 4.	
1880, April 26.	"
1862, Dec. 30.	Ogden, Samuel. 10, *Manley Street, West.*
1884, April 15.	Okell, Samuel, F.R.A.S. *Ouseley, Langham Road, Bowdon.*
1861, Jan. 22.	O'Neill, Charles, F.C.S., Cons. Mem. Ind. Soc. *Mulhouse. Glen Allen, Manley Road, Whalley Range.*
1844, April 30.	Ormerod, Henry Mere, F.G.S. 5, *Clarence Street.*
1861, April 30.	Parkine, James. *Rochdale.*
1876, Nov. 28.	Parry, Thomas, F.S.S. *Gorsfaur House, Ashton-under-Lyne.*
1865, Nov. 17.	Phillips, Henry Harcourt, F.C.S. 183, *Mare Lane East, Manchester.*
1854, Jan. 24.	Prochin, Henry Davis, F.C.S. *Belmont Hall, Cromley.*
1854, Feb. 7.	Ramsbottom, John, M. Inst. C.E. *Fernhill, Alderley Edge.*
1859, April 19.	Ransome, Arthur, M.A., M.D., Cantab., F.R.S., M.R.C.S. 1, *St. Peter's Square.*
1888, Feb. 21.	Rée, Alfred, Ph.D., F.C.S. 121, *Manchester Road, Middleton.*
1869, Nov. 16.	Reynolds, Osborne, LL.D., M.A., F.R.S., M. Inst. C.E., Professor of Engineering, the Owens College. *Ladybarn Road, Fallowfield.*
1884, April 3.	Rhodes, James, M.R.C.S. *Glossop.*
1880, Mar. 23.	Roberts, D. Lloyd, M.D., F.R.S.Ed., F.R.C.P. (London). *Ravenswood, Broughton Park.*
1889, April 6.	Robertson, W. J., *Morley Lodge, Heaton Moor, Stockport.*
1864, Dec. 27.	Robinson, John, M. Inst. C.E. *Westwood Hall, Leek.*
1858, Jan. 26.	Roscoe, Sir Henry Enfield, B.A., LL.D., D.C.L., F.R.S., F.C.S., M.P. 10, *Bramham Gardens, Wetherby Road, London, S.W.*
1890, Jan. 21.	Sacré, Howard C., *Breeze House, Higher Broughton.*
1851, April 29.	Sandeman, Archibald, M.A. *Garry Cottage, near Perth.*
1870, Dec. 13.	Schorlemmer, Carl, LL.D., F.R.S., F.C.S. *The Owens College.*
1842, Jan. 25.	Schunck, Edward, Ph.D., F.R.S., F.C.S. *Kersal.*
1873, Nov. 18.	Schuster, Arthur, Ph.D., F.R.S., F.R.A.S. *The Owens College.*
1881, Nov. 29.	Schwabe, Edmund Salis, B.A. 41, *George Street.*
1890, Jan. 21.	Sidebotham, James Nasmyth. *Parkfield, Groby Place, Altrincham.*
1890, Nov. 4.	Sidebotham, Edward, *Earlsdene, Bowdon.*
1886, April 6.	Simon, Henry, C. E. *Darwin House, Didsbury.*
1889, Oct. 15.	Tatham, John F. W., M.A., M.D., Medical Officer of Health. *Town Hall, Manchester.*

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OF

THE MANCHESTER LITERARY & PHILOSOPHICAL SOCIETY.

1890-91.

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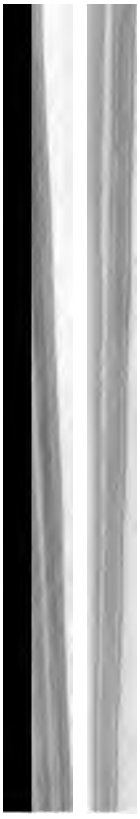

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